Estuary and Ocean Science Supporting Salmon Recovery

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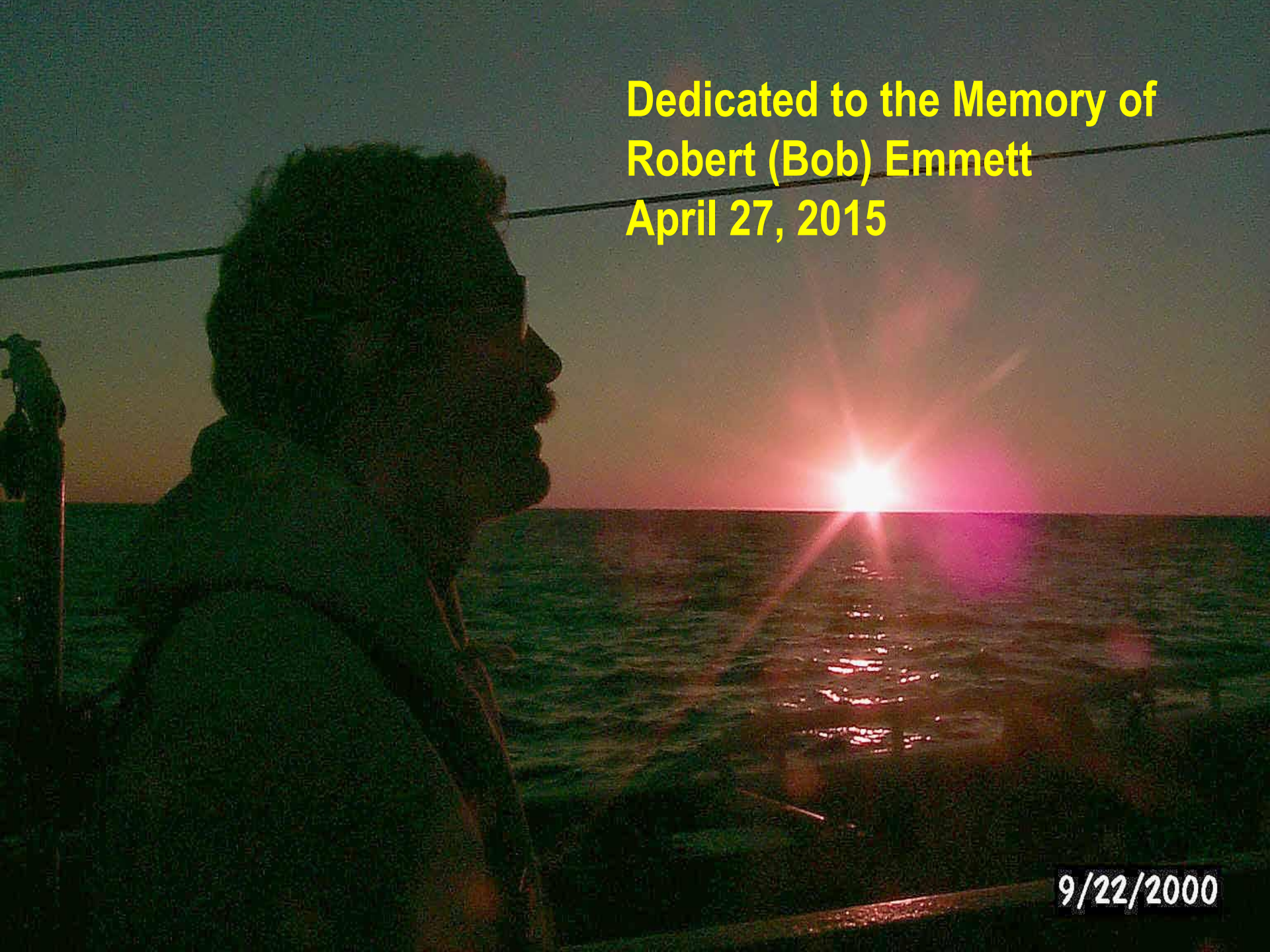
NWC/SWC

Fisheries Ecology Divisions

Kurt Fresh and Sean Hayes

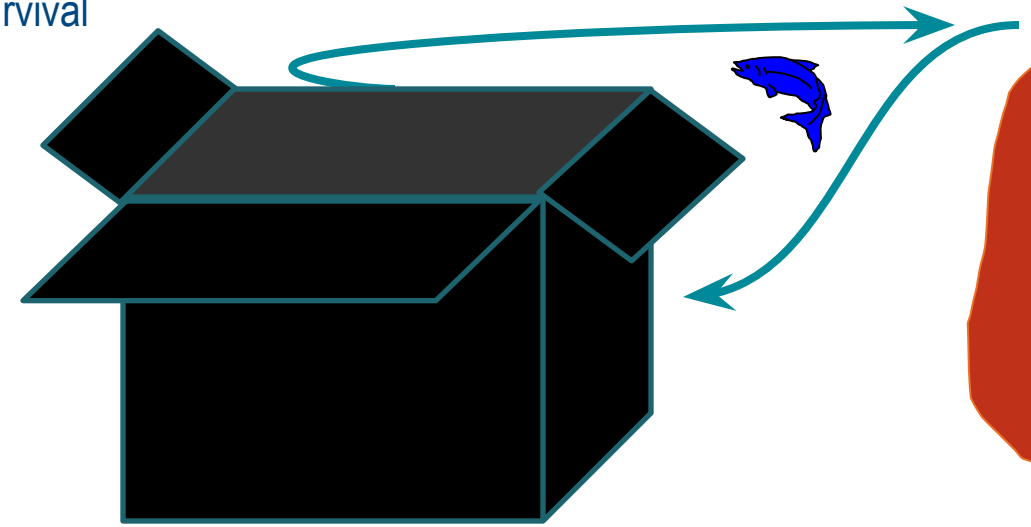
Sections 6.0 and 6.1

Cinco de Mayo, 2015


Dedicated to the Memory of
Robert (Bob) Emmett
April 27, 2015
9/22/2000

Talk Overview

- Background
- Objectives
- Conceptual framework
- Case studies
  - Ocean Science
    - Juvenile salmon studies- WA, OR and CA
    - Newport Line
    - Central valley early marine survival
  - Estuary Science
    - Coastal Rivers
    - Columbia River
    - Puget Sound



CONDITIONS IN THE 1970's HELPED SHAPE WHERE WE ARE TODAY

- Estuaries- Fish management paradigms were misguided.
  - We managed for most abundant members of a population.
  - We concluded estuarine dependent life history types did not contribute.
  - Survival was the major metric to judge success.
- Ocean- It trumped all, was so big, so why study it. We cannot do anything about it.

Implications:

- Habitat change in estuaries has been significant.

Estuarine Habitat Change

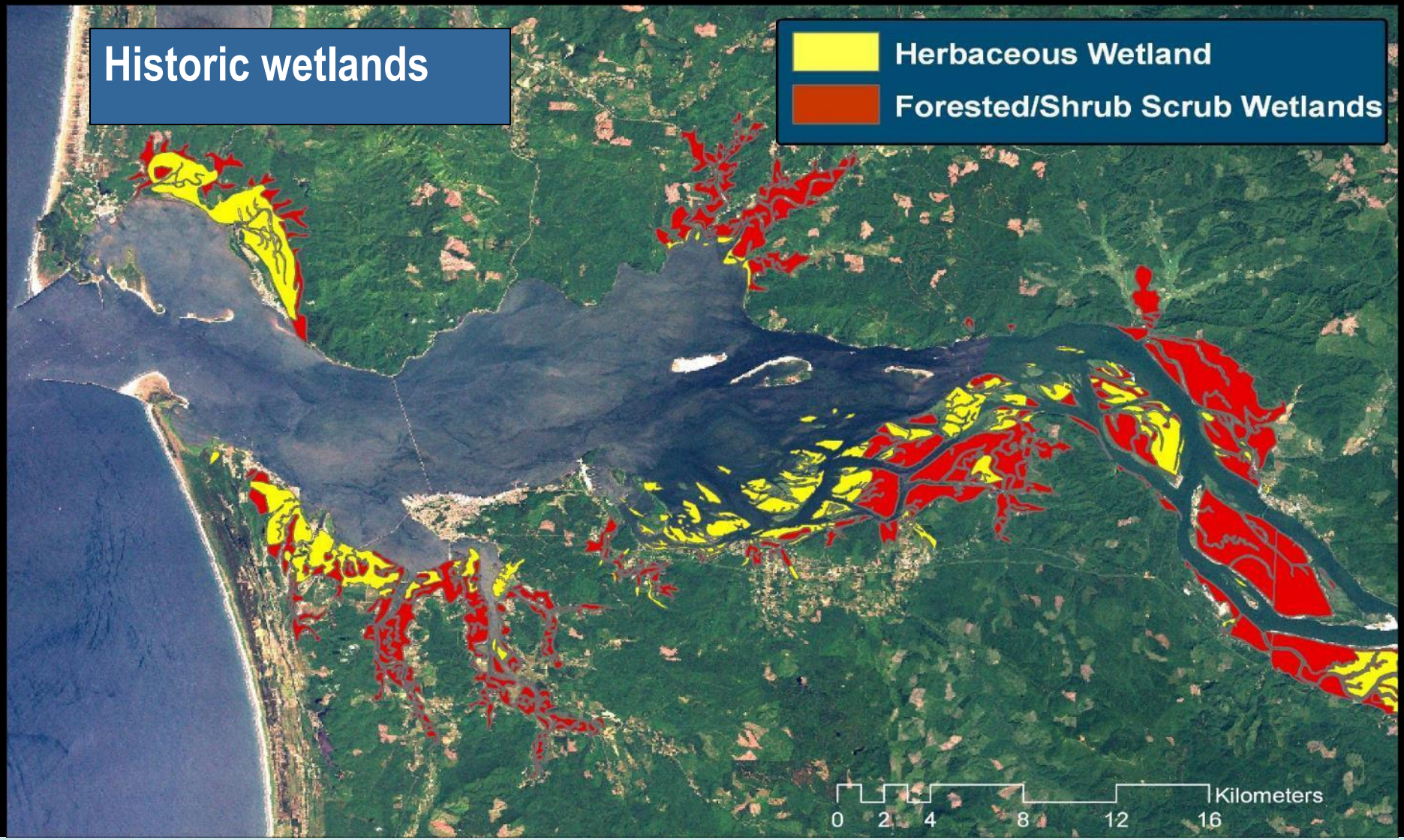


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Image by: Jennifer Burke, UW

Estuarine Habitat Change

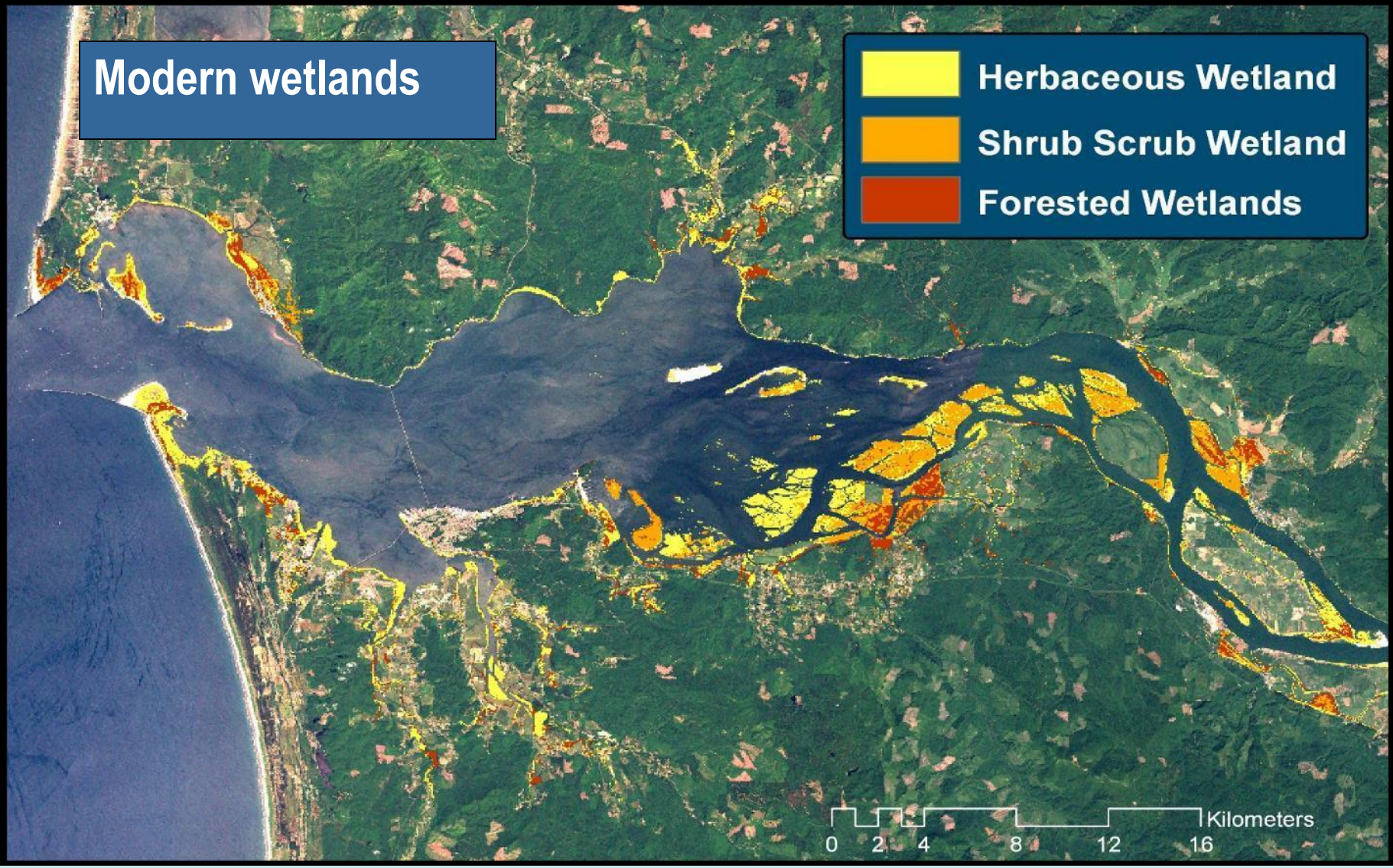

Image by: Jennifer Burke, UW

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Major Objectives of Ocean and Estuary Science

- Monitor effectiveness of restoration actions.
- Collect science needed to develop and implement recovery efforts.
- Understand factors affecting salmon population characteristics (e.g., growth, survival, diversity) in estuary and ocean habitats.

Case Studies

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Case Study- The Ocean

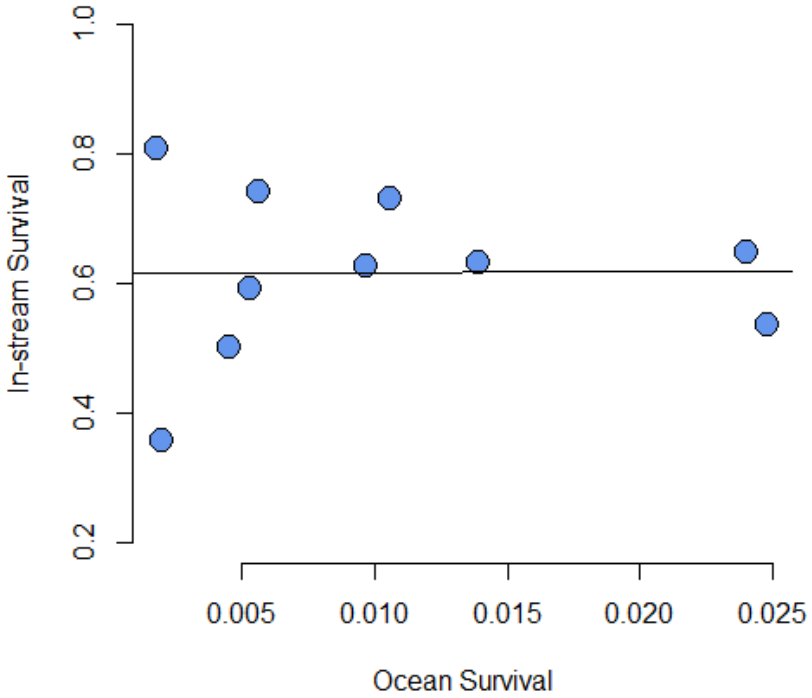
Why Study the Ocean

Provide an understanding of the role of ocean conditions on growth and survival of salmon.

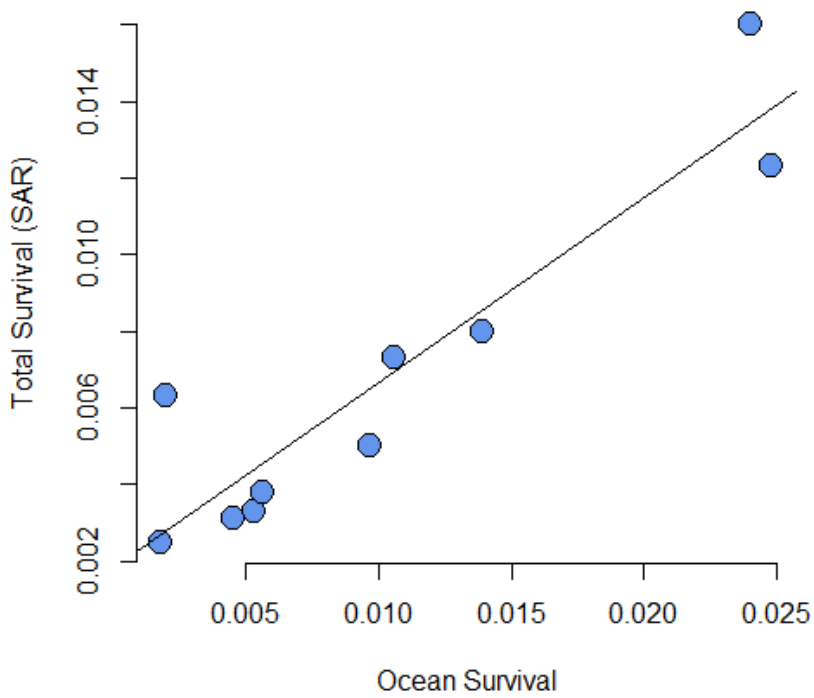
Provide context for recovery actions- define relative roles of marine and freshwater factors on survival.

Why Study the Ocean- It is Important

Ocean survival is *not* related to in-river survival



Ocean survival is related to total survival (SAR)



In-River Survival Varies by a factor of 2.5 and Ocean Survival Varies by a Factor of 25.

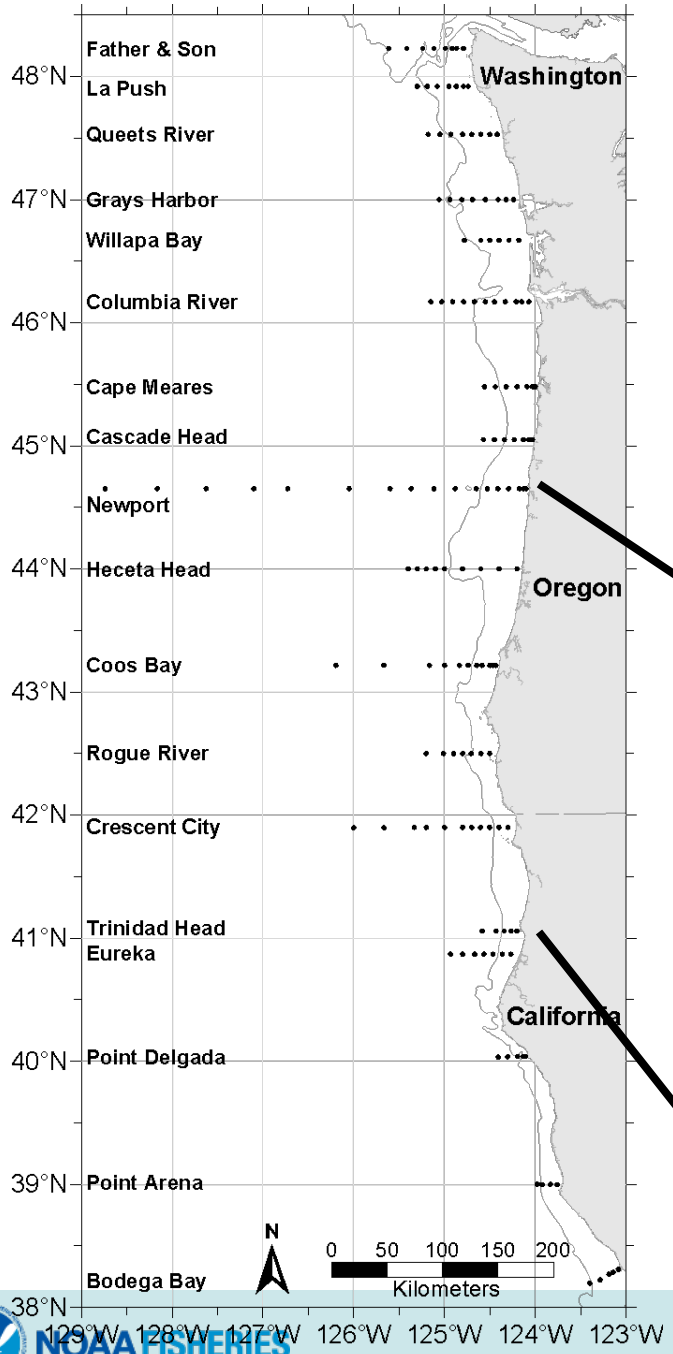
Data is from Hatchery PIT Tagged Snake River Spring Chinook Salmon, Calculated from Lower Granite to Lower Granite

Ocean Salmon Studies

- **SWC**
  - Rivers: Central Valley, Klamath and Coastal Rivers
  - Species: Chinook, Coho, Steelhead
  - Upwelling ecosystem
- **NWC**
  - River: Columbia River.
  - Species: Chinook, Sockeye, Steelhead, Coho.
  - Plume and Upwelling ecosystem

Ocean Salmon Studies

- NWC- 2 primary monitoring studies with other research spinning off.
  - **1998 to present: Juvenile salmon in the NCC.**
  - **1996 to present: Newport Line Oceanographic Line**
- SWC
  - **1997-2005- SF Bay and Gulf of Farallones- MacFarlane**
  - **2010- 2015- Central CA to Central OR- joint survey**
- SWC/NWC- strong collaboration, cooperation, coordination of ocean work.



Northern California Current Coastal Pelagic Ecosystem: Oceanographic Data

"The Newport Line" and Trinidad Line

Newport Line Oceanography

1. Started in 1996. Biweekly data.
2. Only long term data on NCC
3. Three funding sources at present
4. Increasingly more difficult to support.

Trinidad Line- SWFSC

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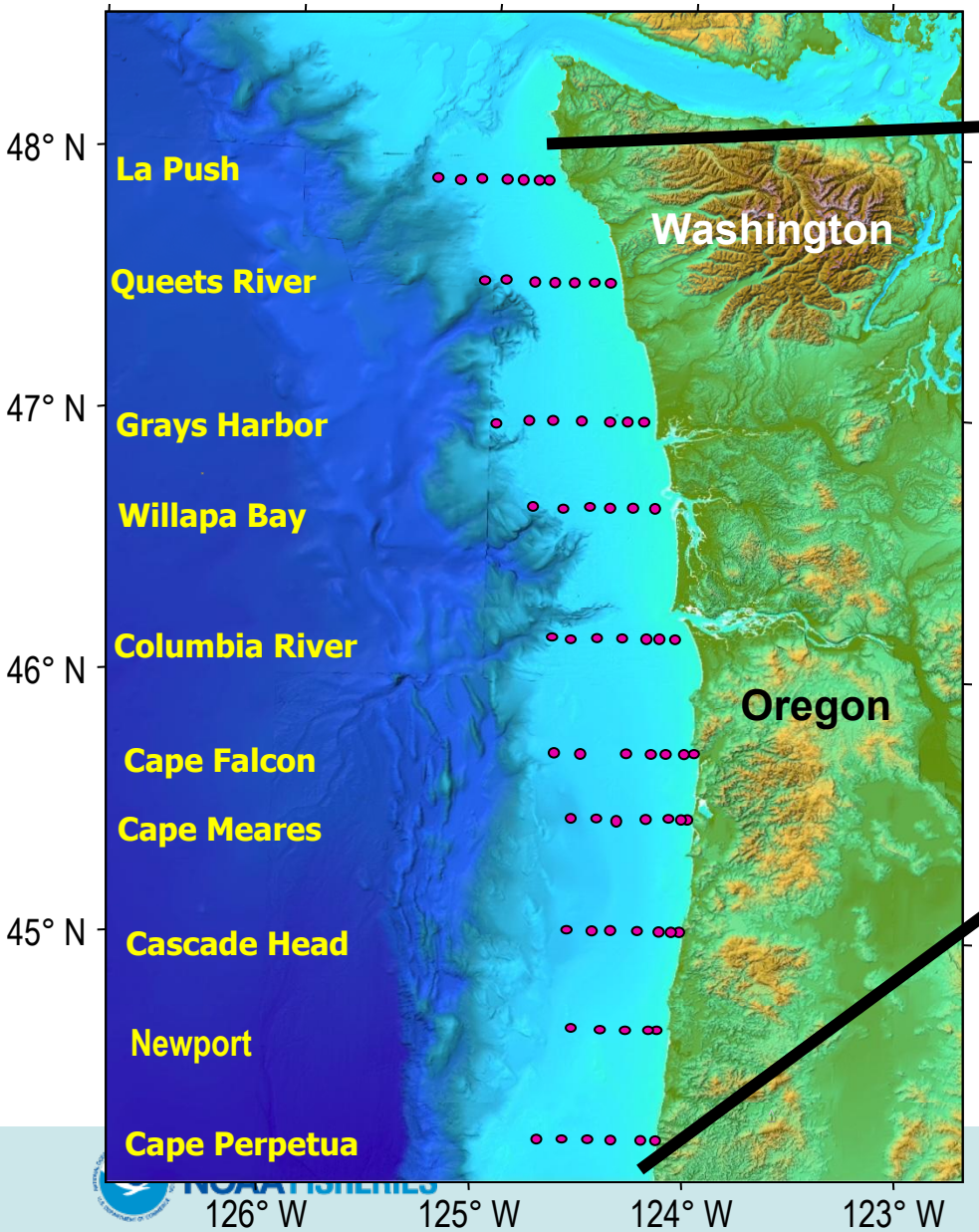
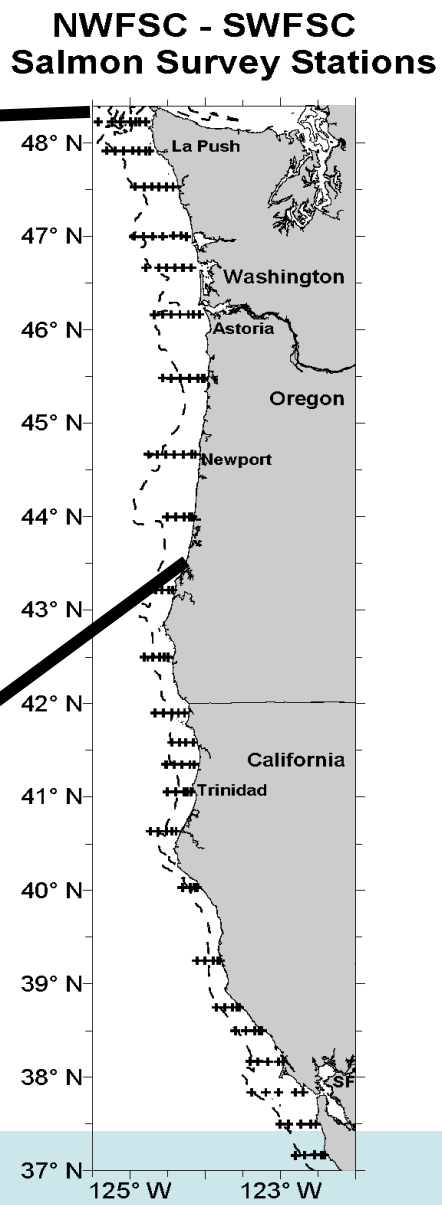
Newport Line

- Provide high resolution, long term data on water quality and plankton in the NCC.
- Used in forecasting adult salmon returns and survival to the Columbia River.
  - Brian Burke's Presentation
- Used in NCC IEA work.

Ocean Salmon Studies

NWFSC Juvenile Salmon Ocean Studies

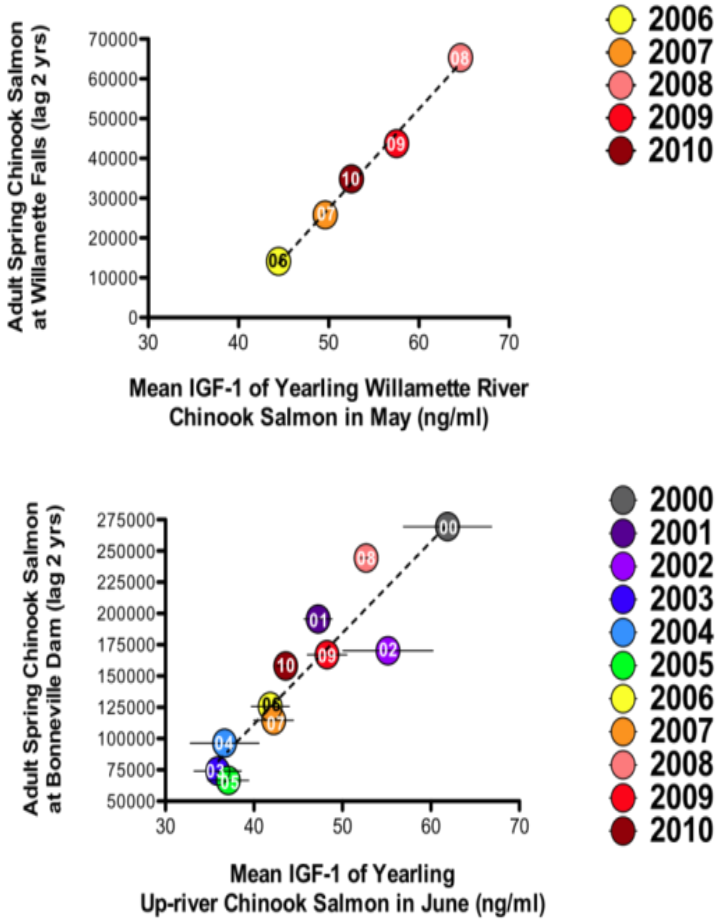




Sampling methods

- Juvenile salmon caught with surface trawl: sometimes with a small mesh liner
- Plankton nets
- Other: buckets, CTDs
- Acoustics
- Bird and marine mammal observations
- NWC- May, June Sept for18 yrs
- SWC- June, Sept, 5 yrs

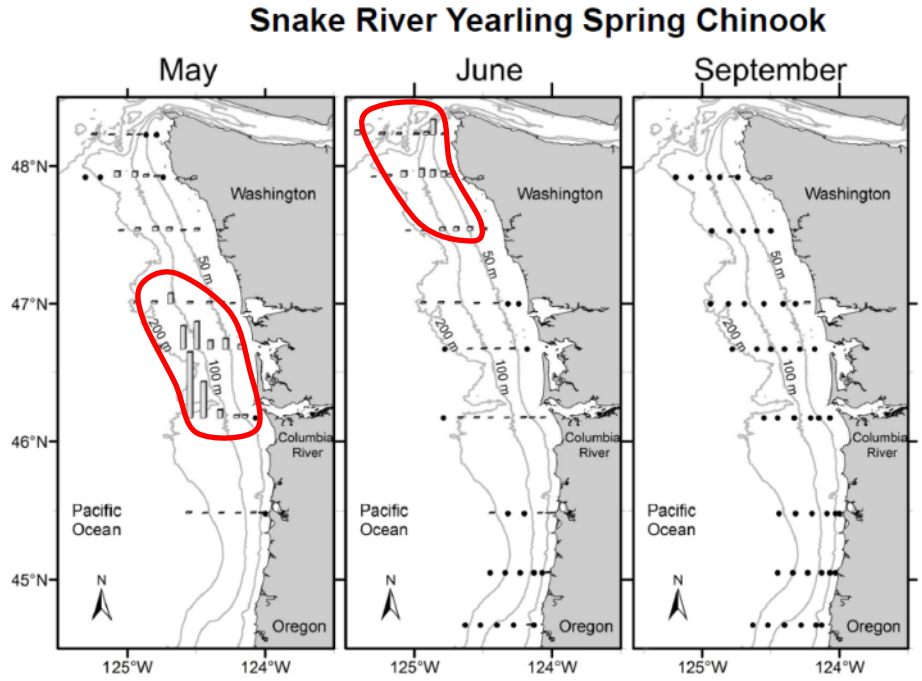
NWC- Early Marine Life May be a Critical Period to Many Columbia River Salmon Stocks

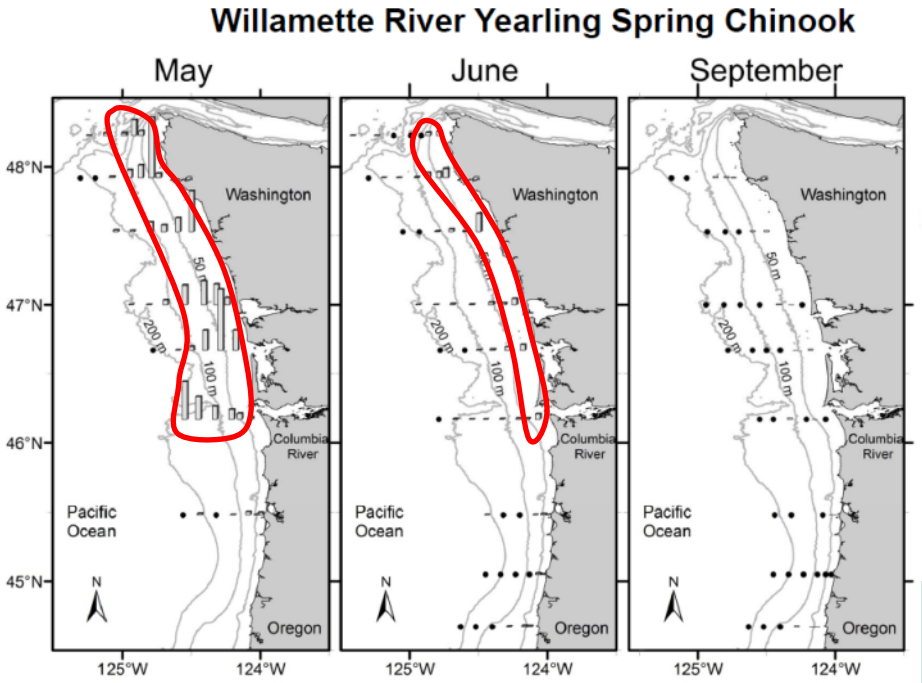


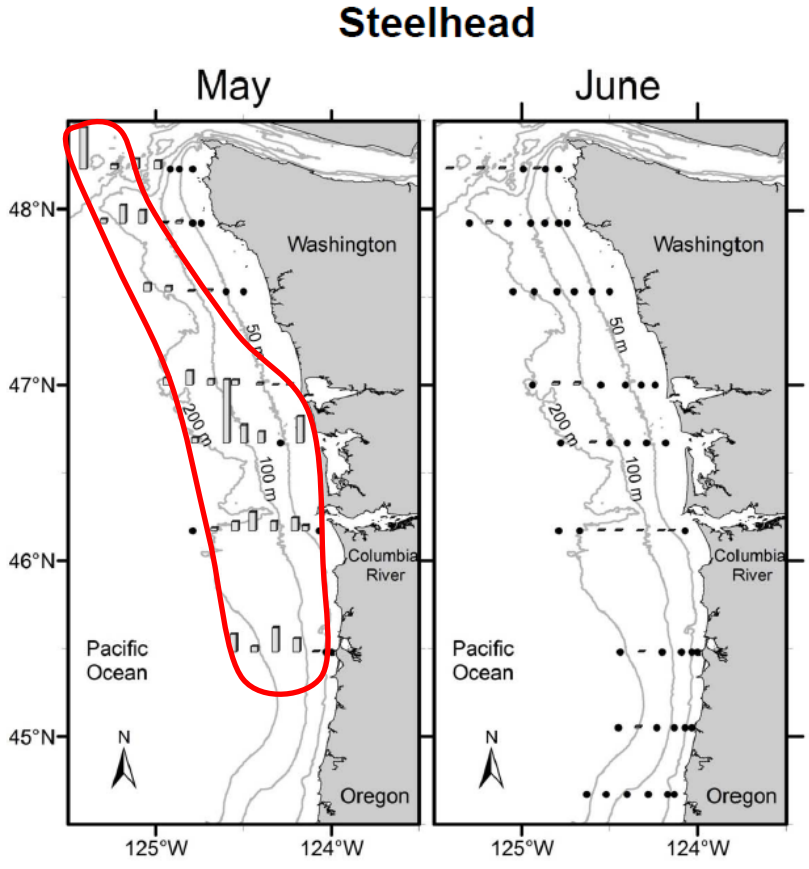
An Example:

Early Ocean Growth is Strongly Related to Survival of Yearling Stocks of Chinook Salmon

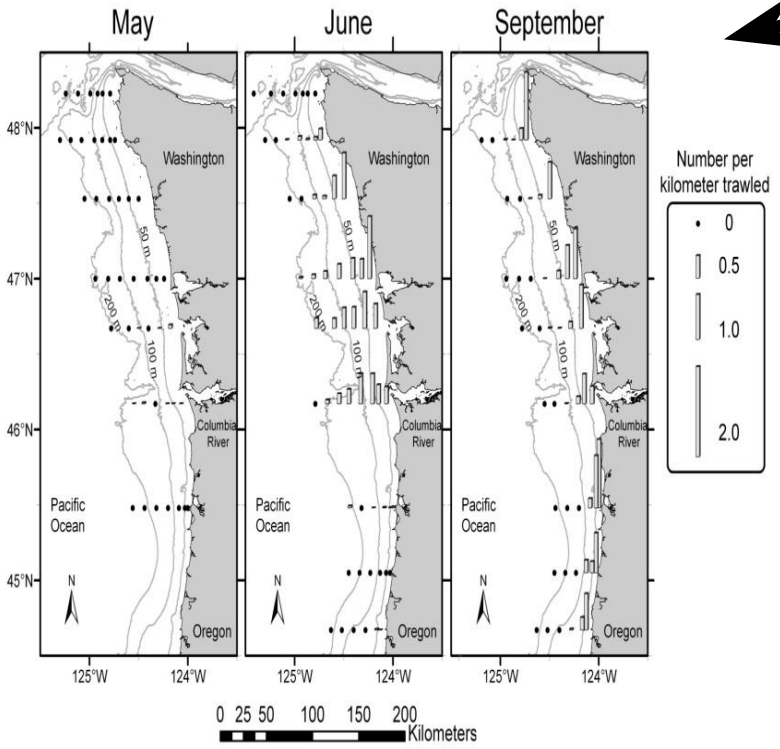
Patterns of Ocean Habitat Use Differ Between Different Species and Life History Type



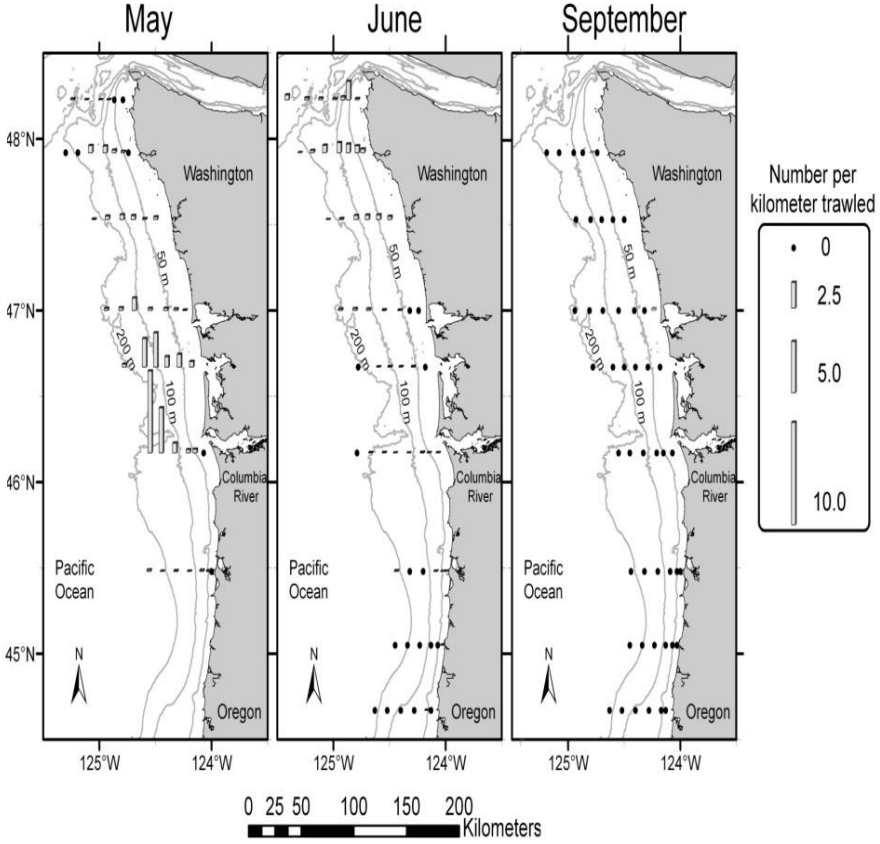




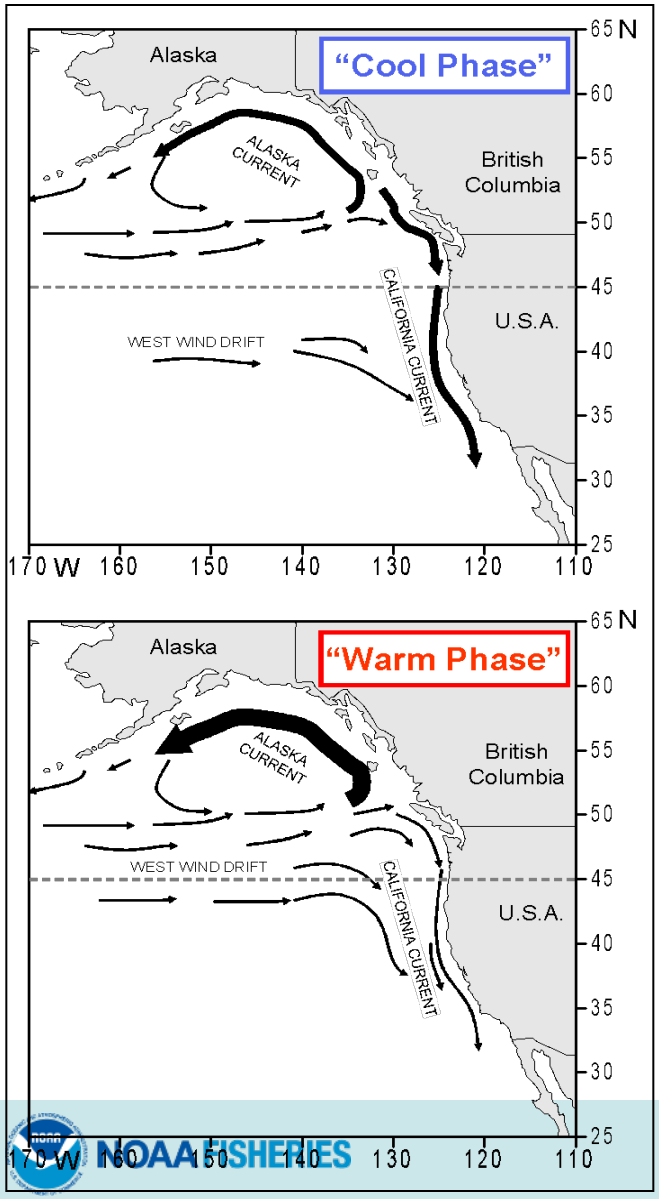
Snake River Sub-yearling
Fall Chinook



Snake River Yearling
Spring Chinook



Climate Affects on Salmon Operate at Multiple Scales



Cool Phase of PDO=High Survival

- Flow from the North
- Cold water – Lipid-rich copepods
- Low number of large predators

Warm Phase of PDO=Low Survival

- Flow from offshore & South
- Warm water – Low lipid copepods
- Large number of predators

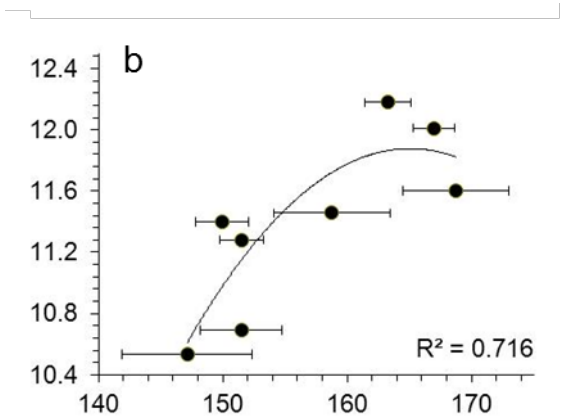
PDO=Pacific Decadal Oscillation

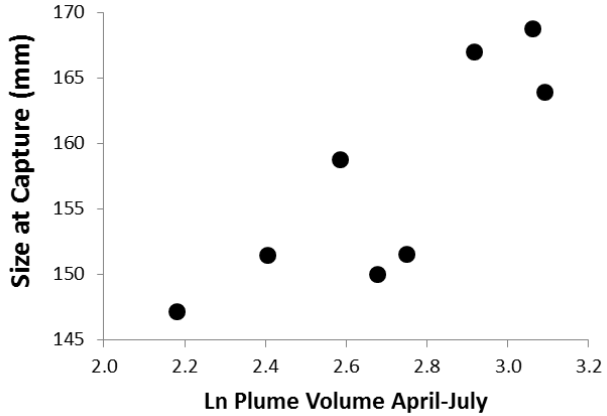
Regional Processes are Important As Well

The Columbia River Plume

The Plume- It Can be Related to Adult Salmon Returns

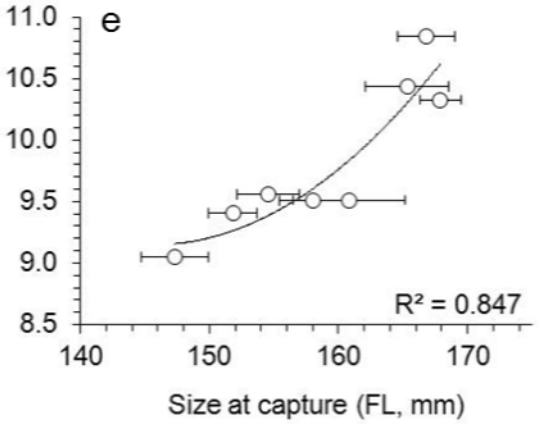
Snake River spring Chinook

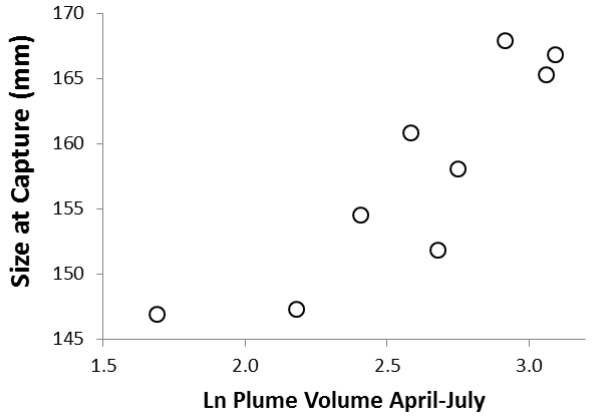




Adult returns (-2 yr)

Mid-upper Columbia River spring Chinook





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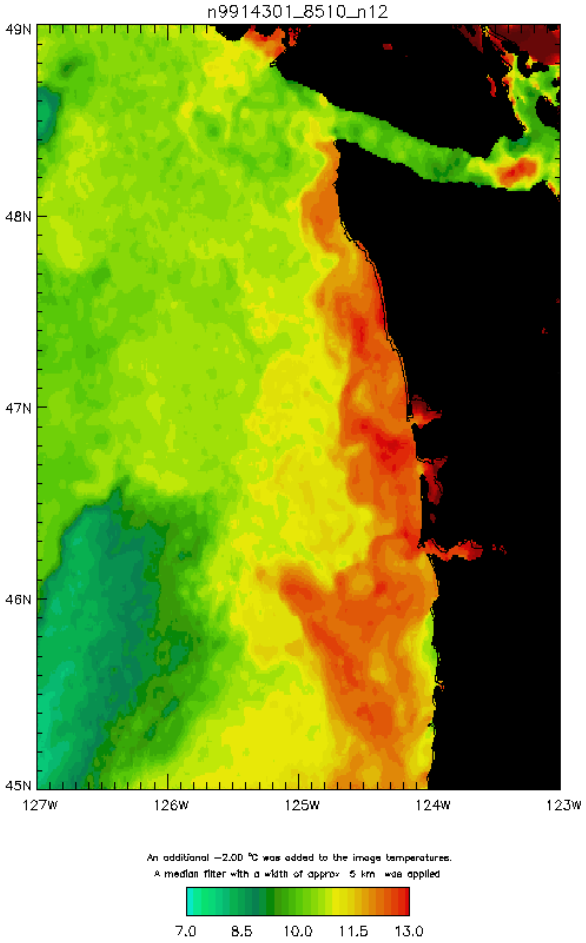
from Tomaro et al. 2012 and
J. Miller et al. (In prep.)

We Can Affect Attributes of the Plume

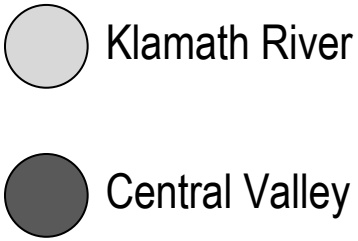


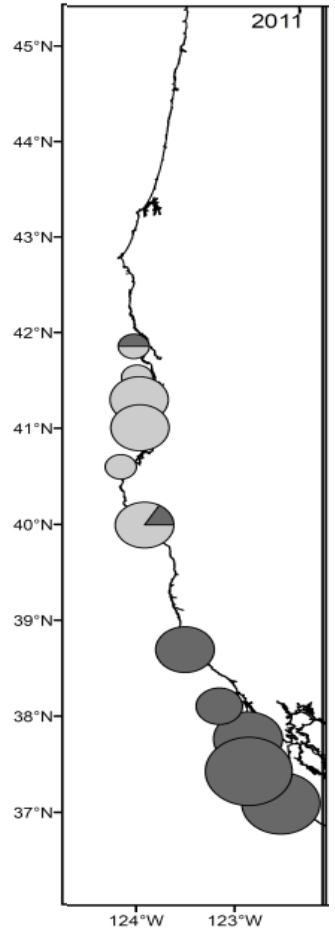
- About 44% of variability in plume volume is explained by river discharge at Bonneville Da. Coastal winds explains ~30% of the plume variability

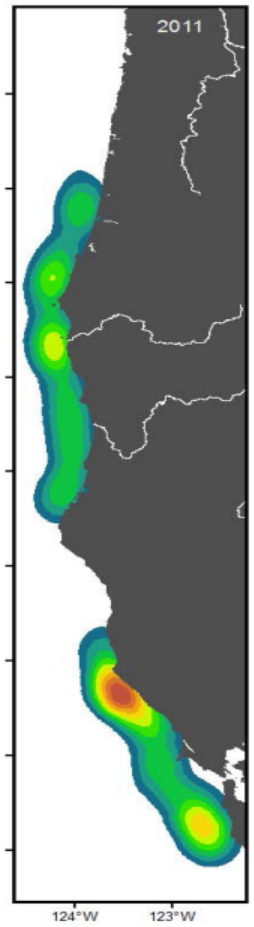
Juvenile Chinook distribution in an upwelling ecosystem

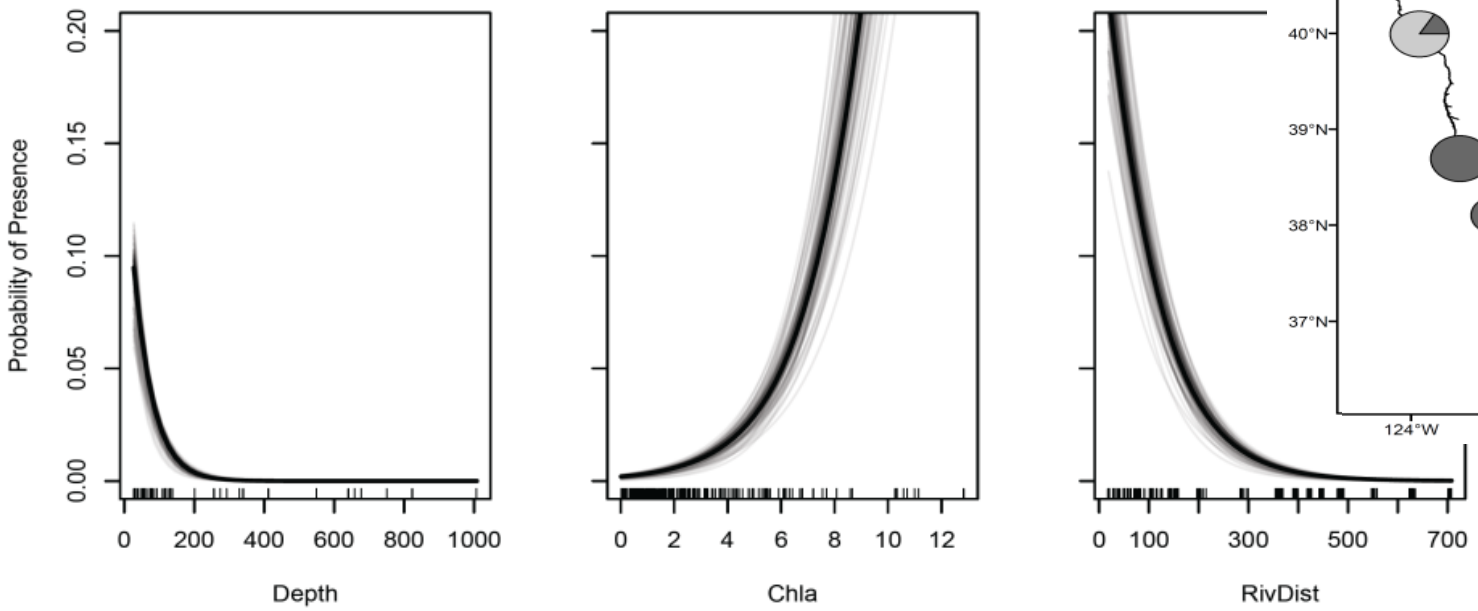
(California & Southern Oregon)

- Juvenile salmon found:
  - Shallower waters
  - Close to the natal river
  - High chlorophyll a
- Dispersal related to biotic and abiotic oceanic conditions.









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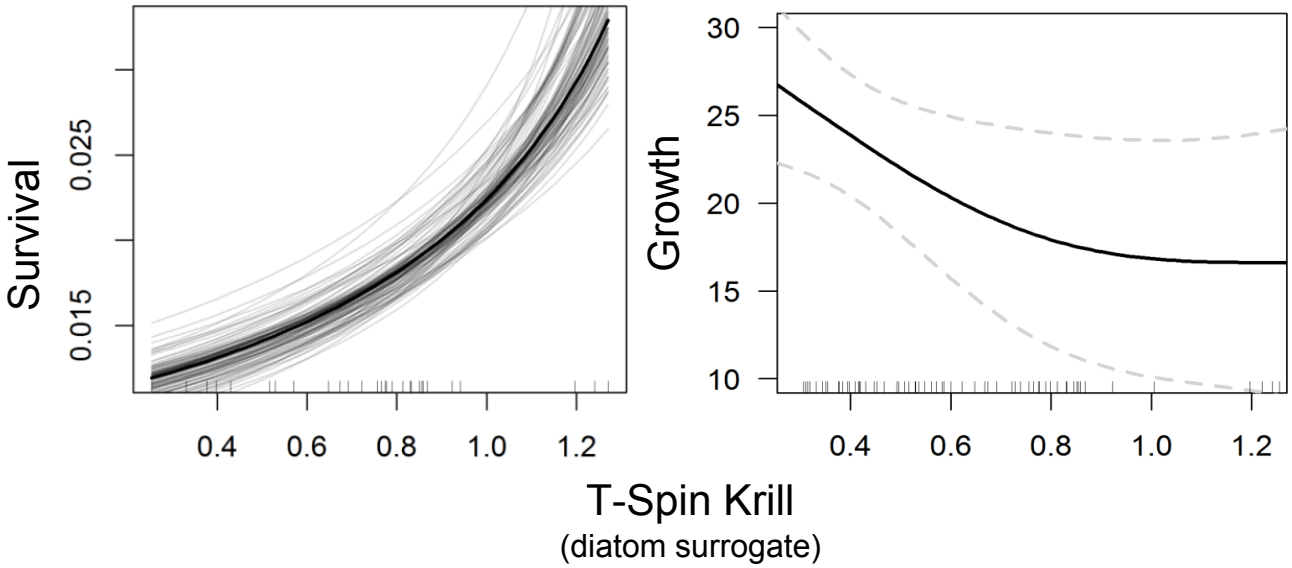
Hassrick, J.L., M.J. Henderson, D.D. Huff, W.J. Sydeman, J.A. Harding, A.J. Ammann, E.D. Crandall, E. Bjorkstedt, J.C. Garza, S.A. Hayes.

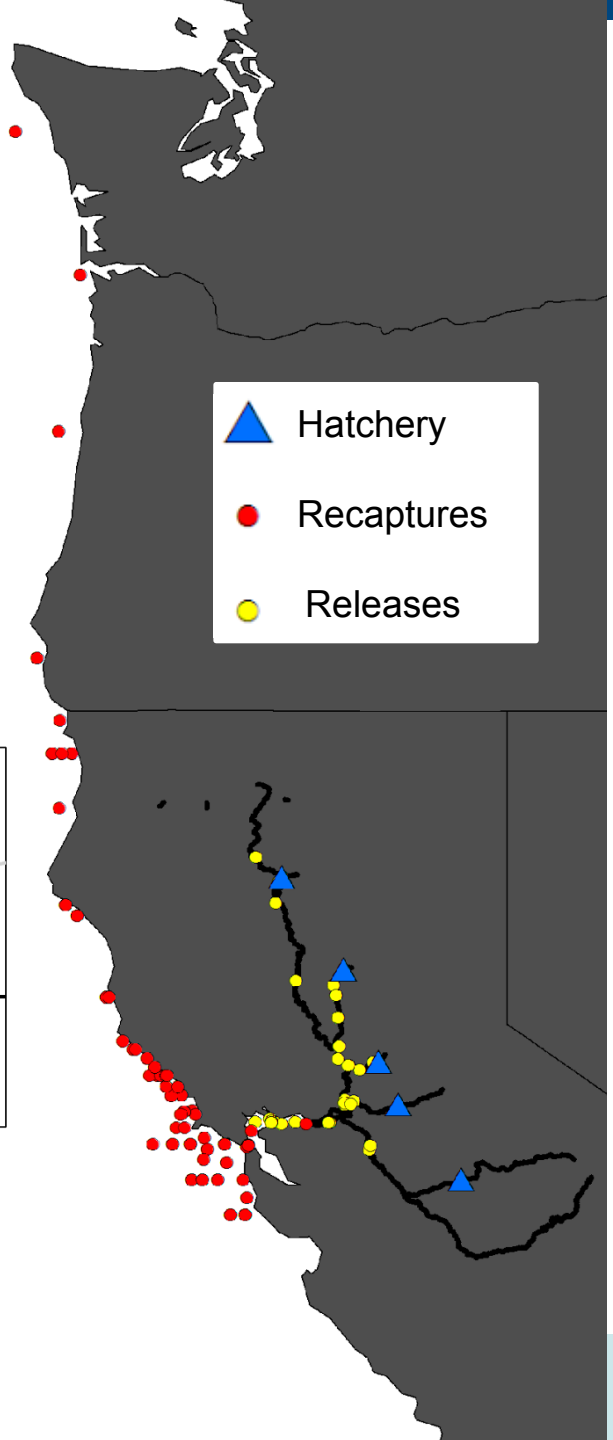
CV Fall Run- CWT Growth and Survival Study

Objectives: Discern relative importance of hatchery, river, and ocean conditions on ocean growth/survival of Fall Run Chinook salmon.

Methods: Recover Coded-wire-tags from juveniles and adults to estimate growth and survival respectively.

Preliminary Results:
evidence for ***size-selective mortality***—conditions when survival is low, if small fish are eaten, will appear as high growth.



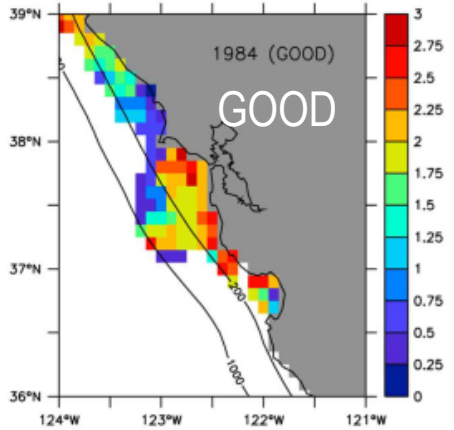


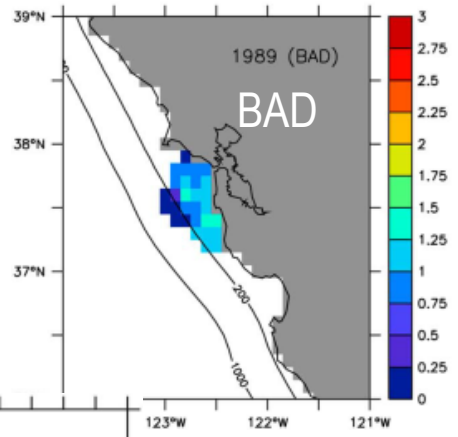
Modeling how ocean effects Chinook growth off California

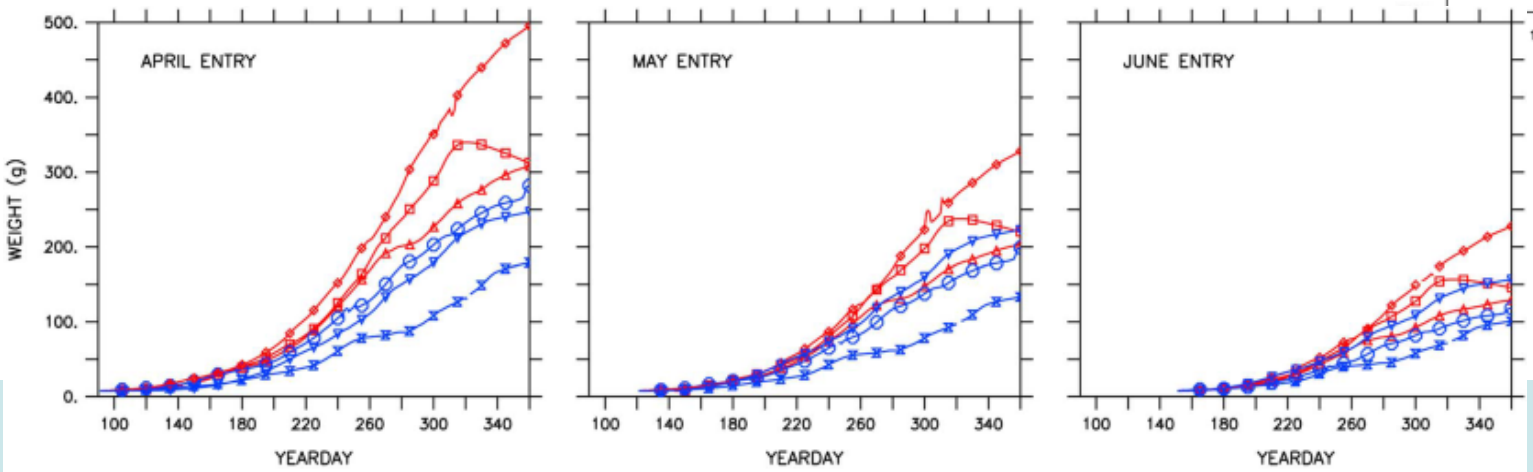
Proof-of-Concept:

- fully coupled ecosystem model tests how ocean conditions + upwelling variability on CV juv Chinook growth
- Individual-Based Model Components:
  - Ocean circulation
  - Biogeochemical (krill, temp, etc)
  - Timing of entry
  - Dynamic Energy Budget (bioenergetics model)
- Modeled growth is consistent with empirical data

Coming attractions: Simulations to test hypotheses generated by the coded-wire tag, diet, and juvenile distribution projects

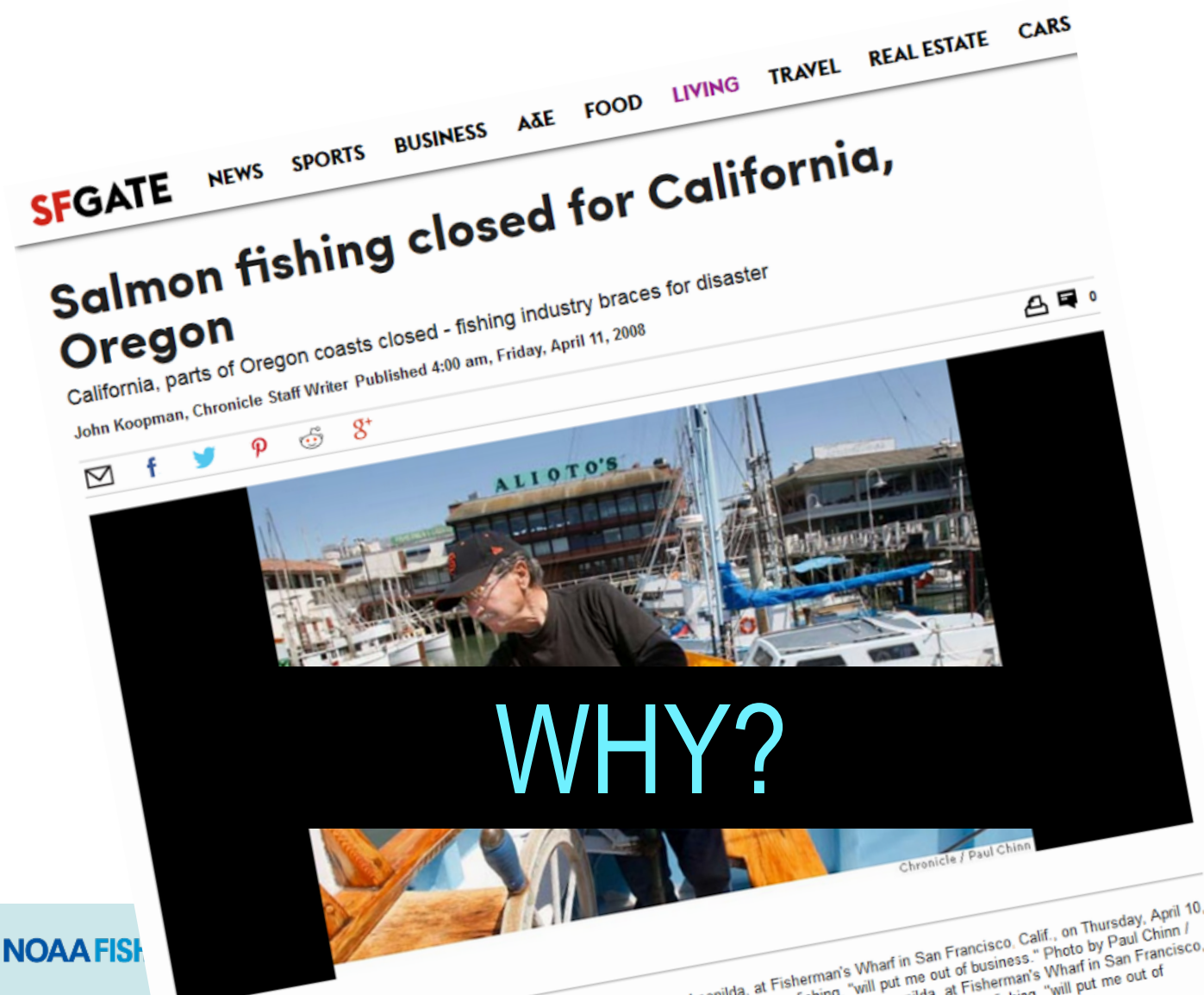






Fiechter, J., et al 2015. Environmental conditions impacting juvenile Chinook salmon growth off central California: An ecosystem model analysis, Geophysical Research Letters. http://onlinelibrary.wiley.com/doi/10.1002/2015GL063046/full

PFMC and NMFS shut down CA Chinook fishery 2008-2009 (and 2010 sorta?)



Did poor ocean conditions drive the crash?

Lindsay E. Woodson, Brian K. Wells, Rachel C. Johnson, Peter K. Weber, R. Bruce MacFarlane George E. Whitman. 2013 Using size, growth rate and rearing origin to evaluate selective mortality of juvenile Chinook salmon *Oncorhynchus tshawytscha* across years of varying ocean productivity. Marine Ecology Progress Series: 487: 163-175

Photo: Andrew Vo

size selective mortality in early ocean phase.

sampling design

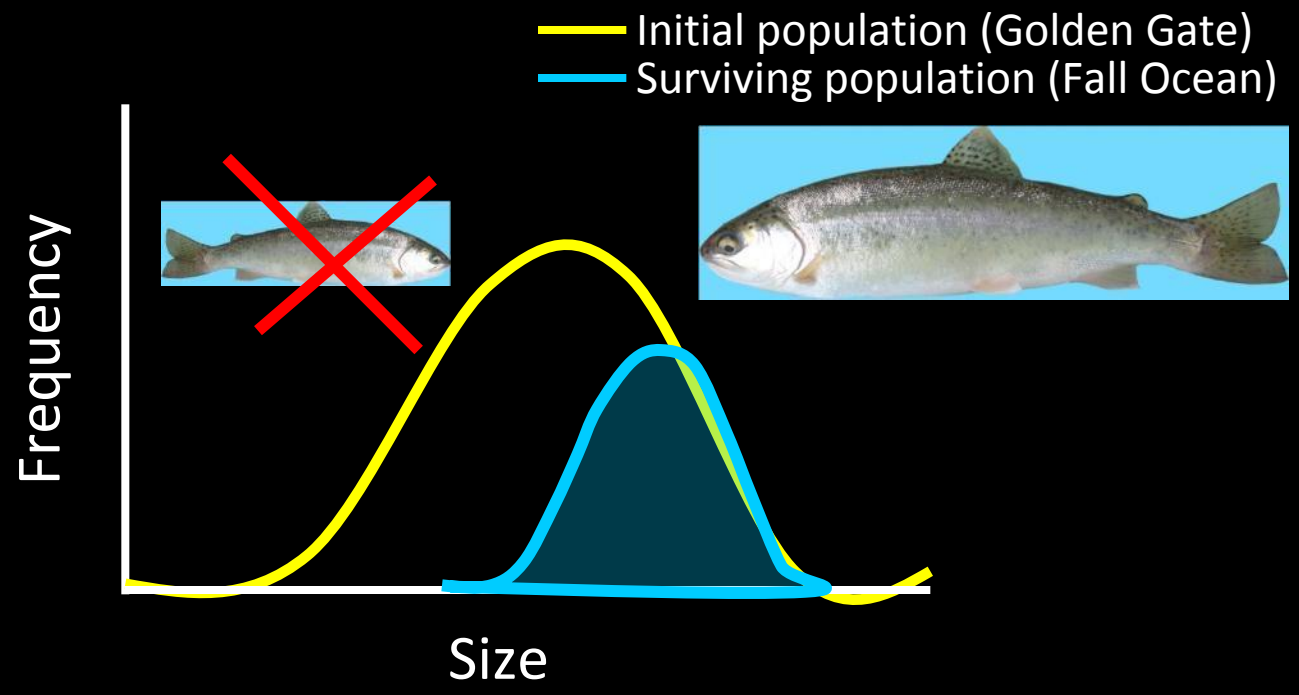
Golden Gate (GG)
May and June

Summer Ocean (SO)
June and July

Fall Ocean (FO)
October

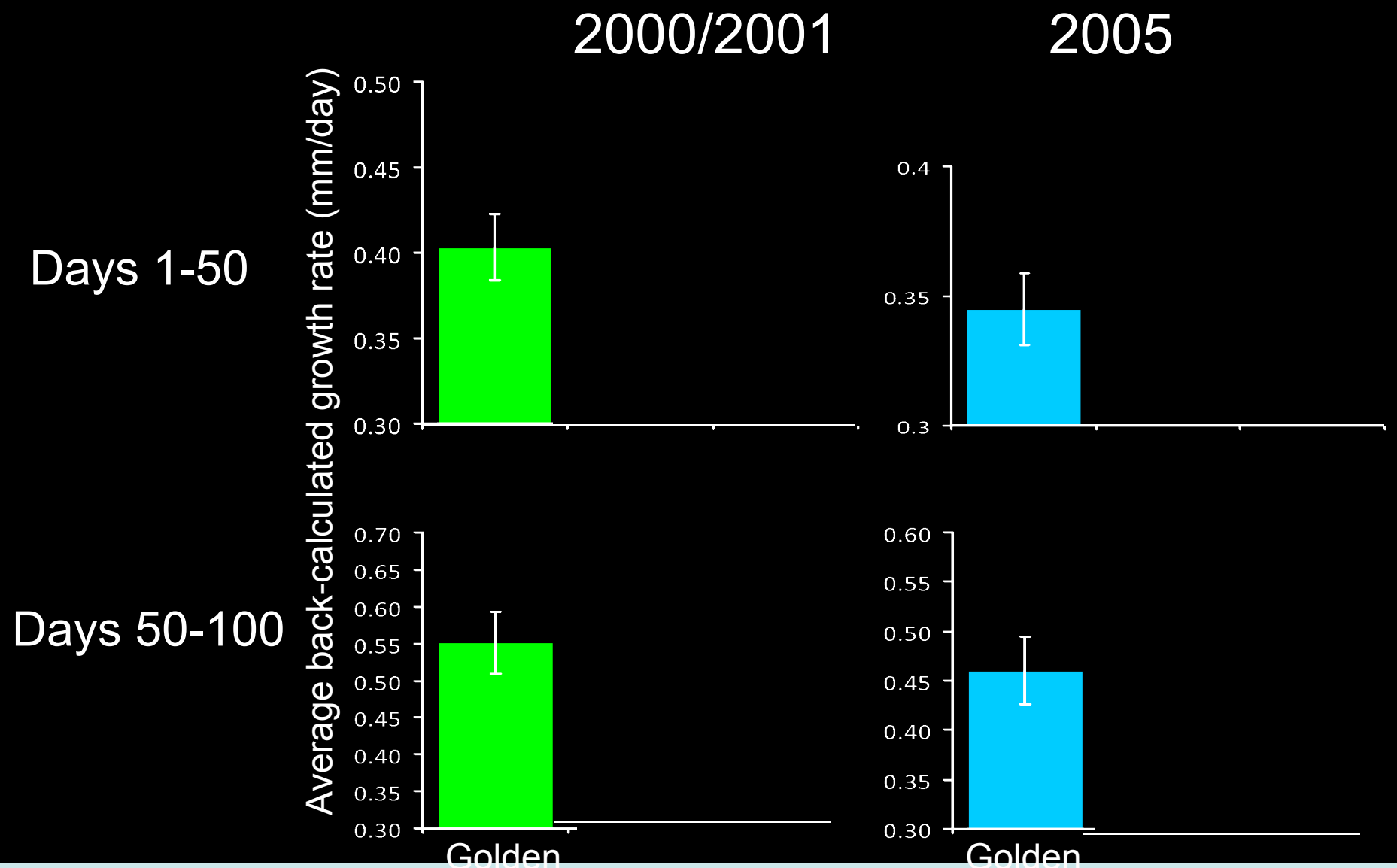
Reconstructing Selective Mortality

If ocean conditions are NOT so good…



Different distributions = Size selective mortality

Freshwater growth



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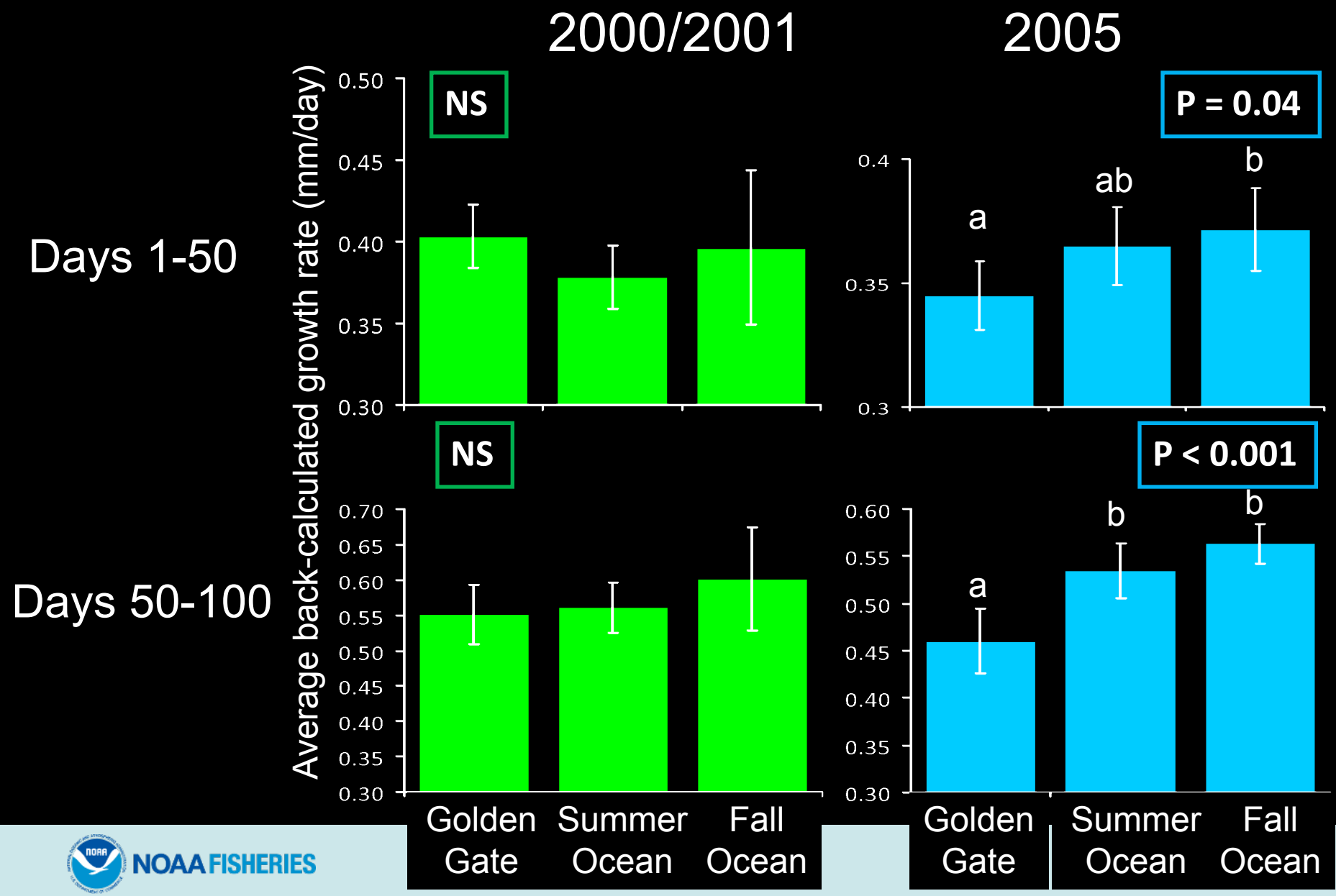
Back-calculated growth rates



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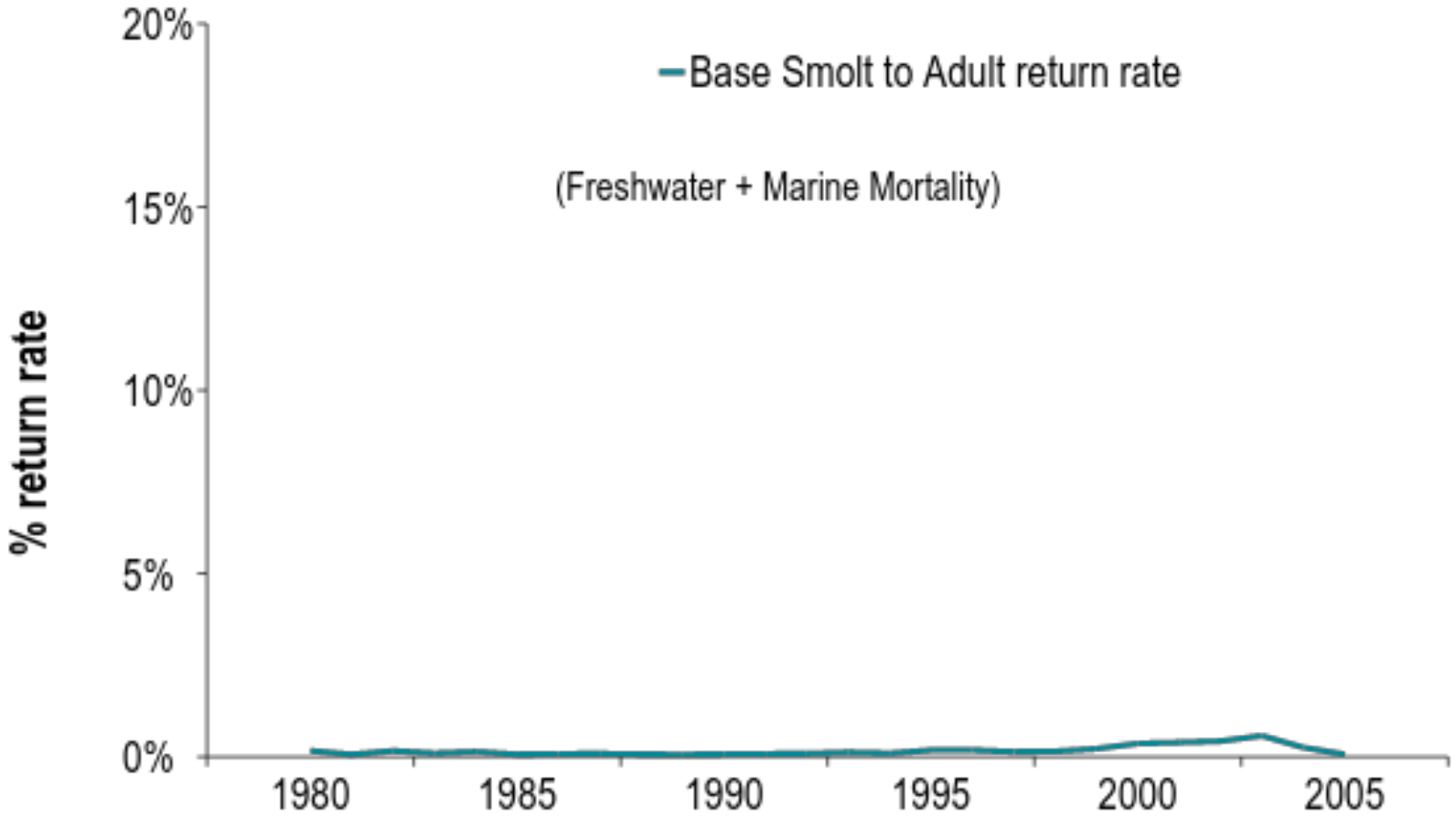
Central Valley Smolt to Adult Return Rate

What is marine survival after river mortality factored out?



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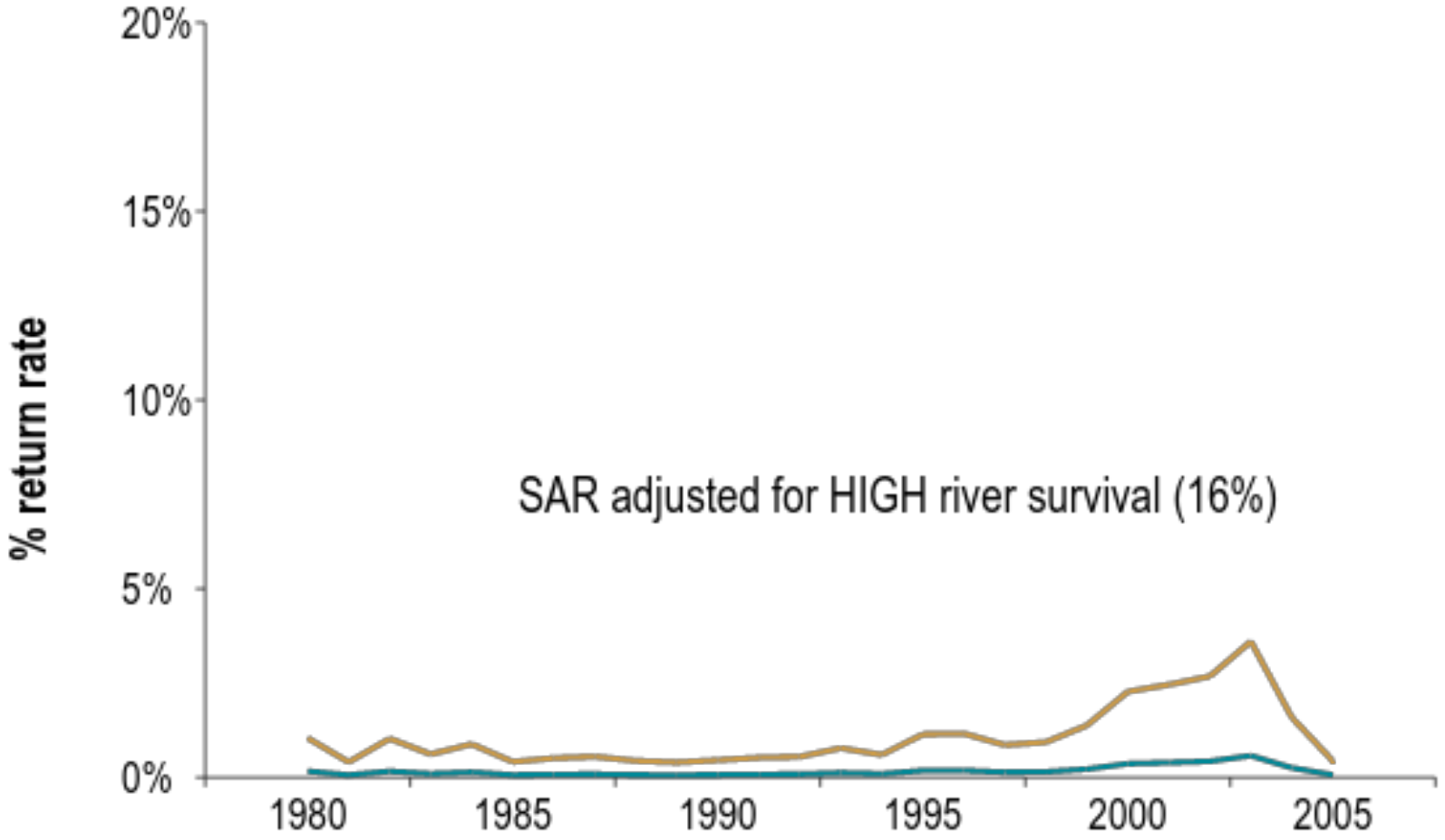

Smolt to Adult Return Rate

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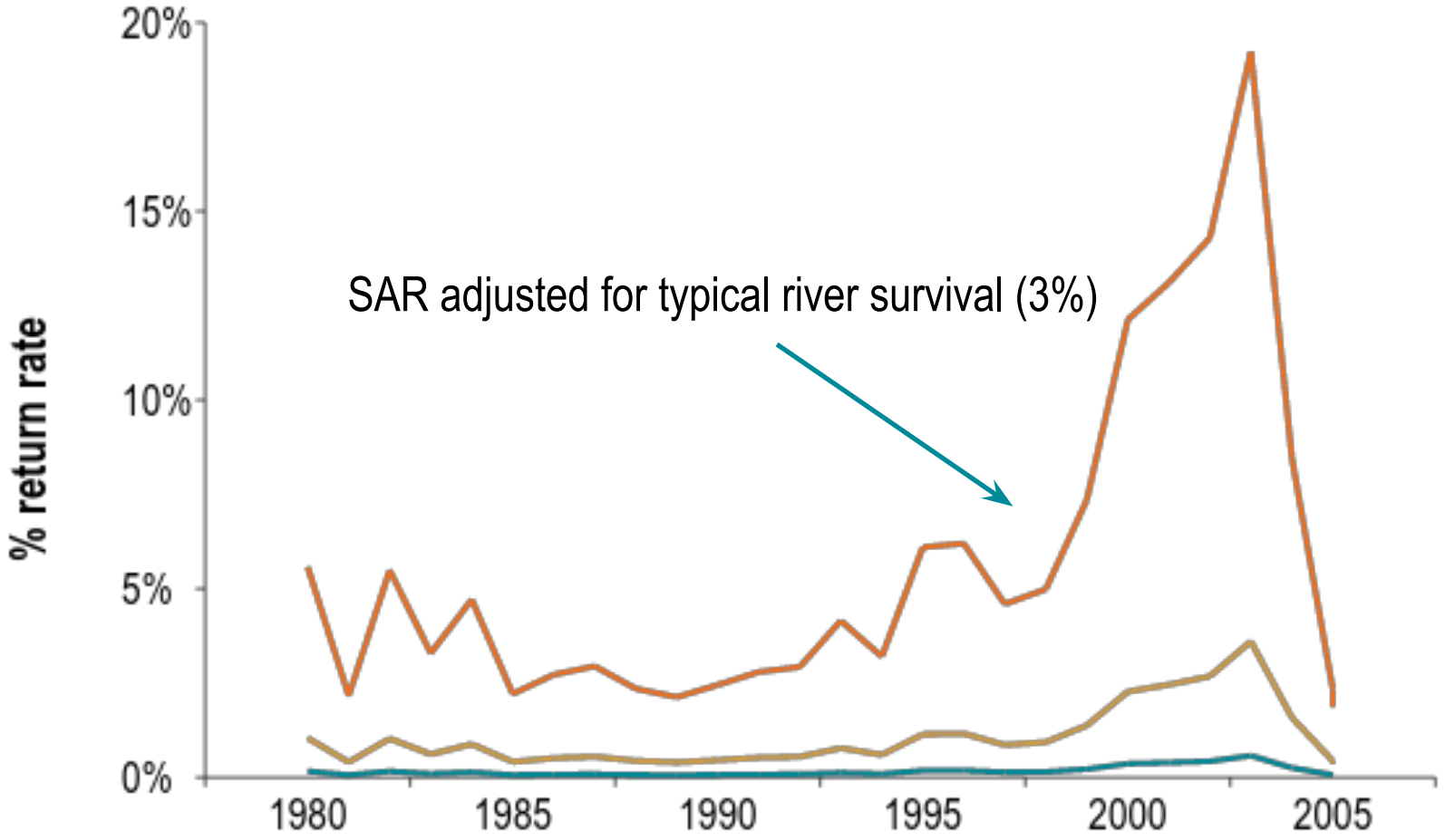


California- What are the implications?

- Rivers/Estuaries - more dangerous than we thought
  - Reduced buffering capacity
  - Are fish selected to get out faster now?
- Ocean- its where salmon go for growth…
  - Presume trade-off with increased mortality but….
  - Could selection favor anadromy because of good growth AND better survival? (is this new?)
- Is the Ocean actually propping California Salmon up?

Lessons Learned- Salmon Ocean Ecology can Advise Management on:

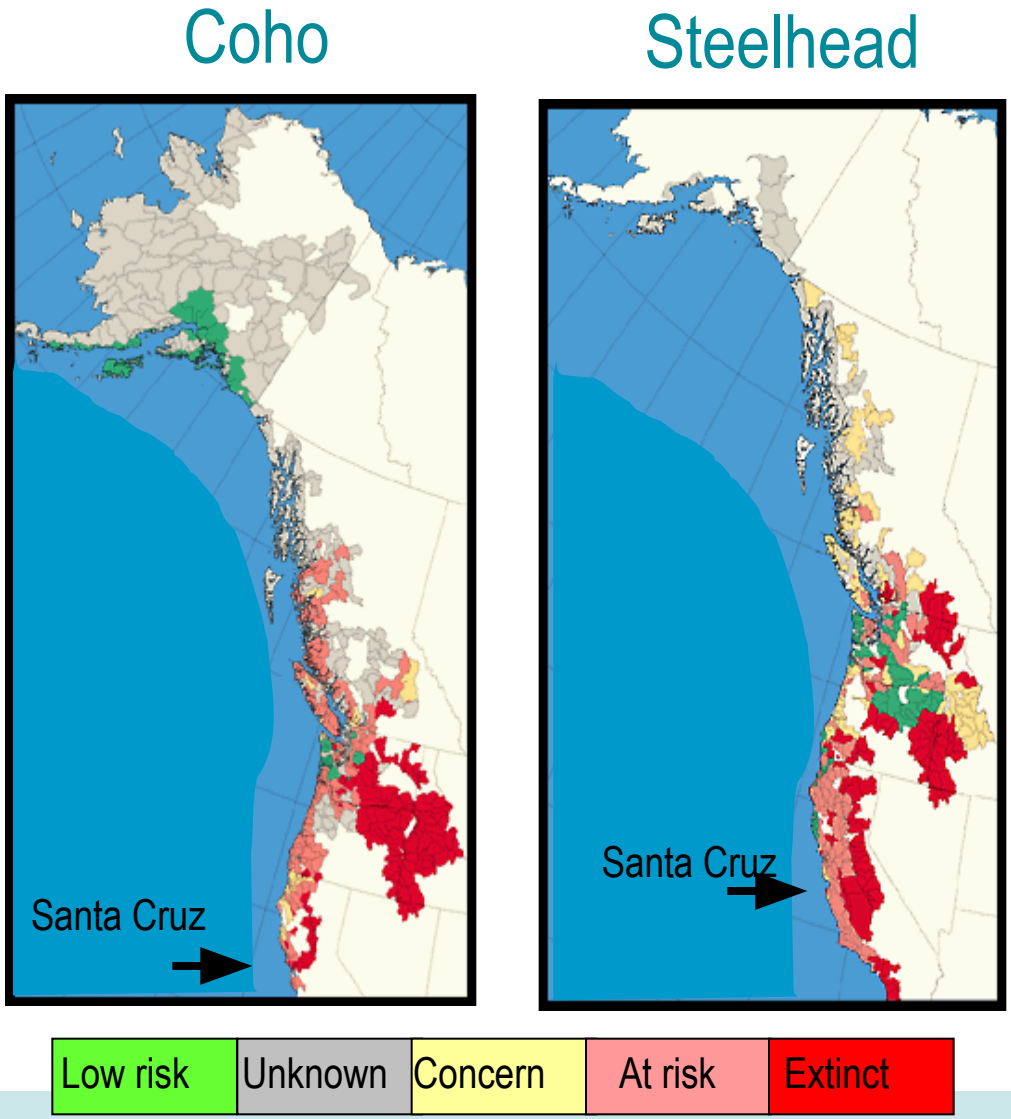
- Top-down and bottom up forces during early ocean life
  - better separation of marine vs. estuarine/freshwater survival
- Factors that affect salmon performance (growth/survival) during early ocean life.
  - We can affect the environment the fish live in (estuary improvement, attributes of the CR plume)
  - We can affect hatchery release-time, size of release and possibly density dependence (Beckman)
  - We can develop predictions of how fish will respond- Forecasting (Burke)

Case Histories Estuaries- The "Question"

- Will improvements in estuarine habitat promote recovery? If so, how do we measure it?
- Estuary habitat is expensive.
- Few studies had clearly established the importance of estuary habitat to salmon and hence the need to restore it.
- No clear link between different life history types and adult returns- for example, do fry contribute.

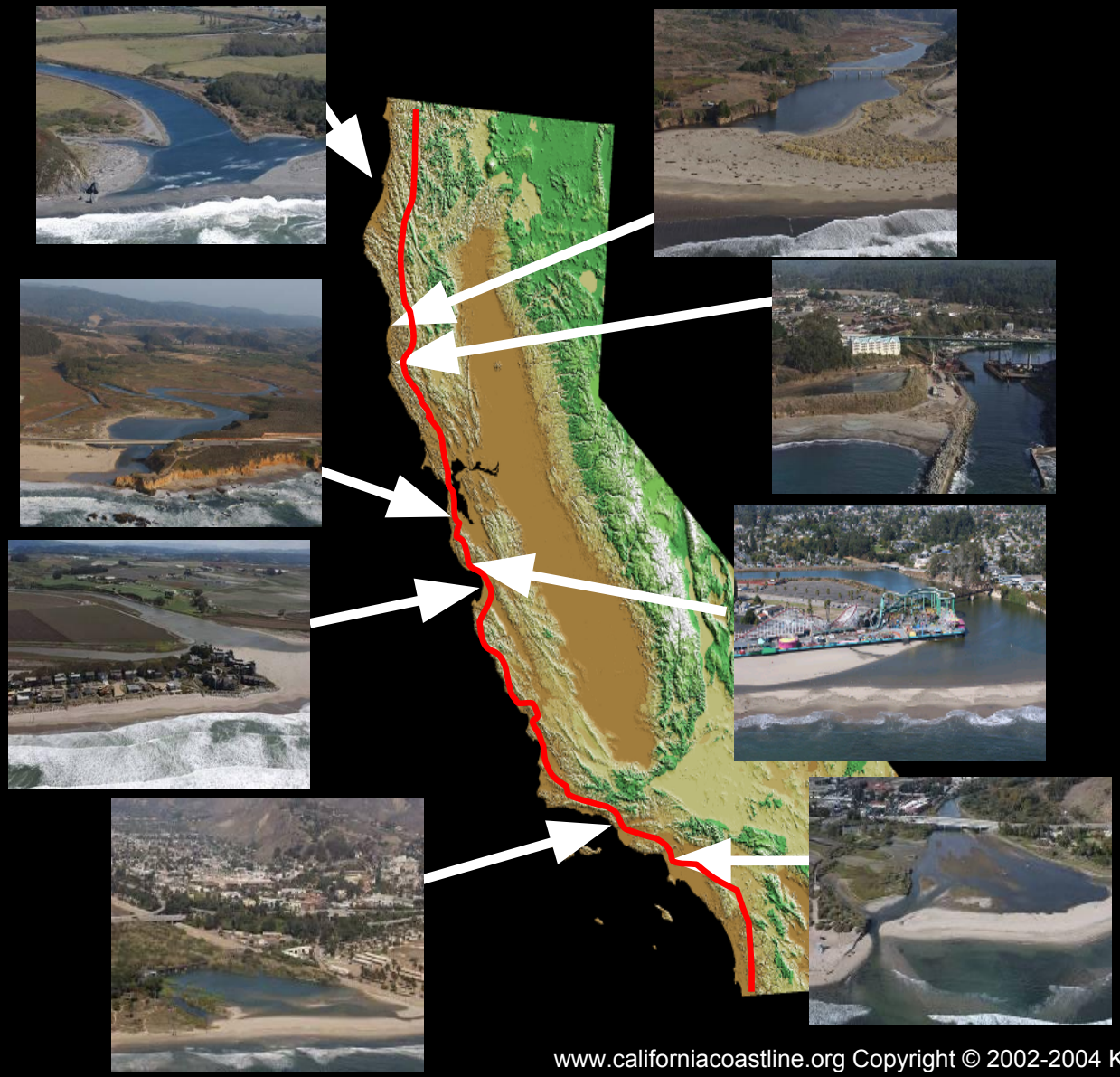
Coastal Watersheds

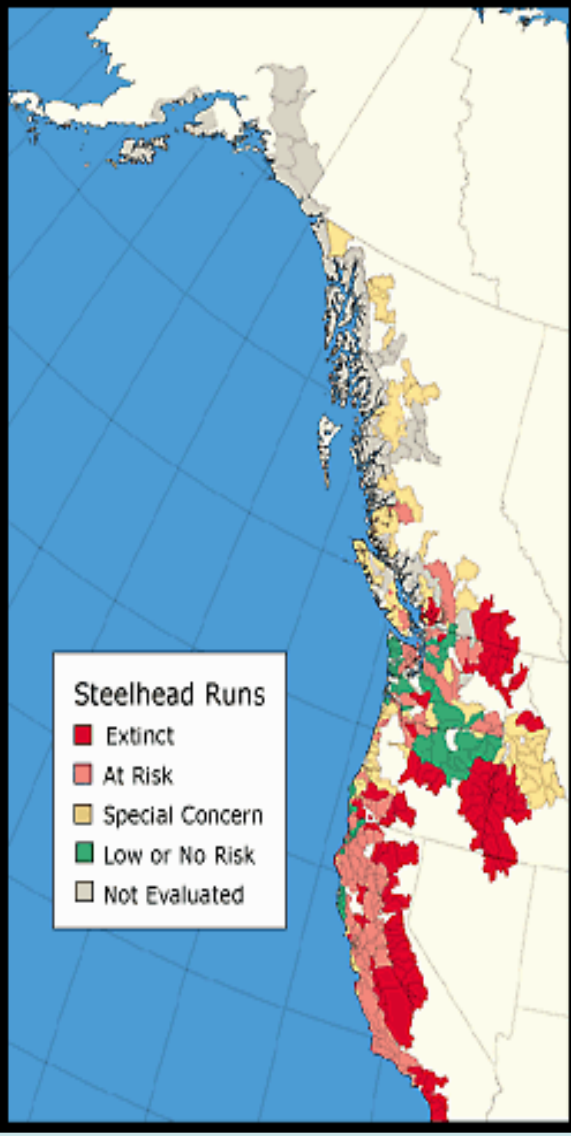
- Scott Creek, California



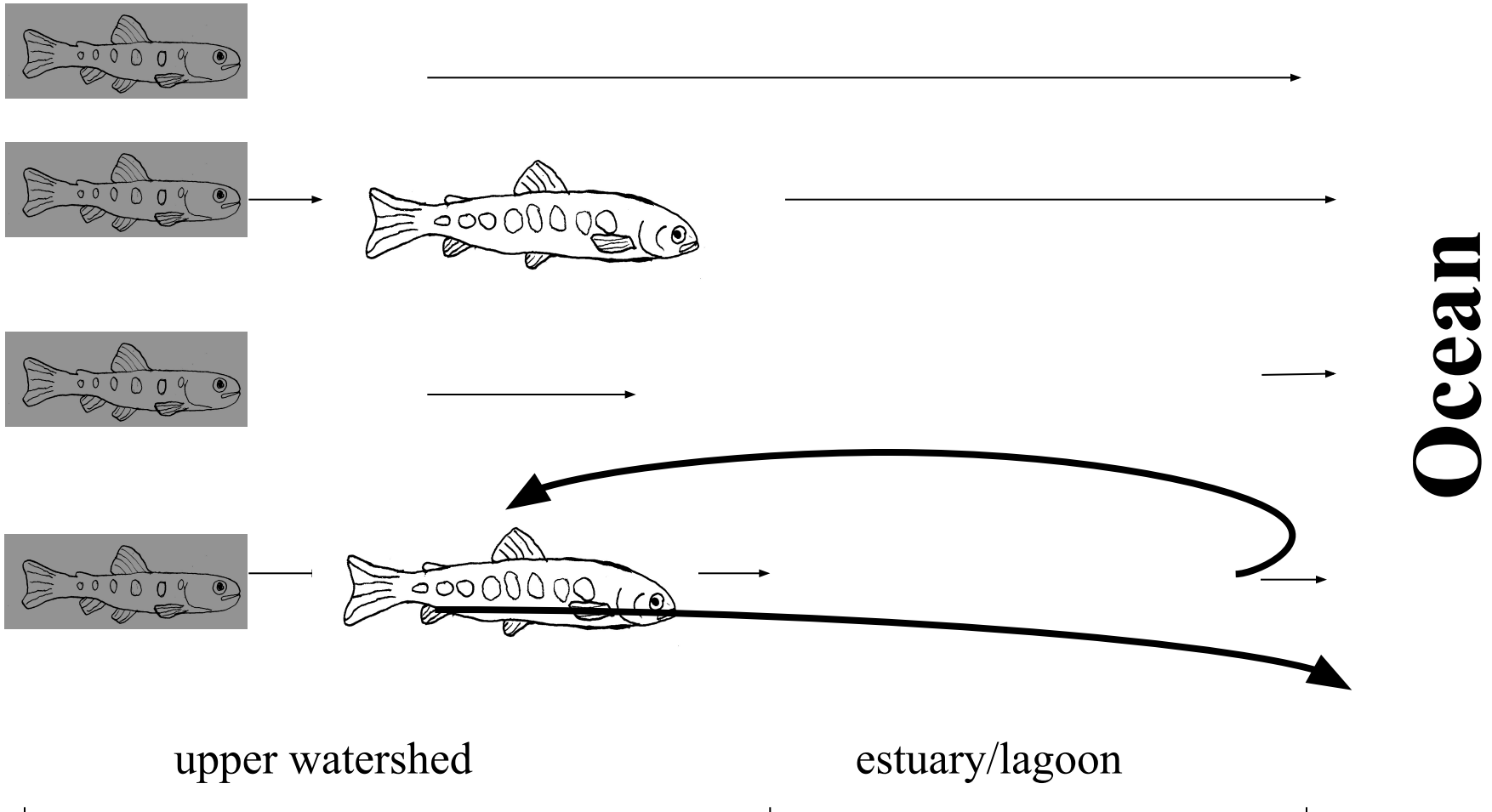

Early 20th century spawning population was
4-10 times larger
Escapement ↑ ??

Steelhead

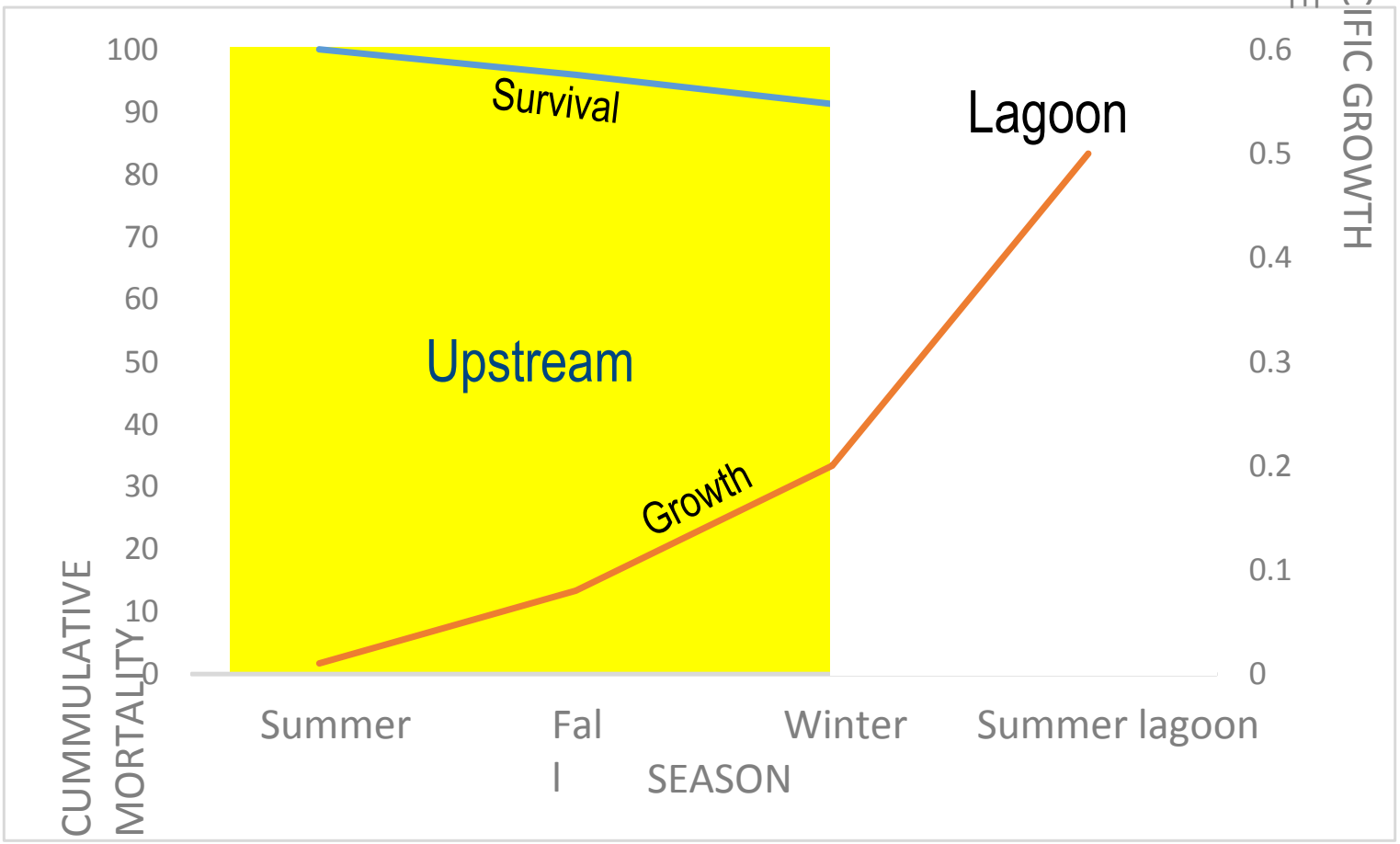




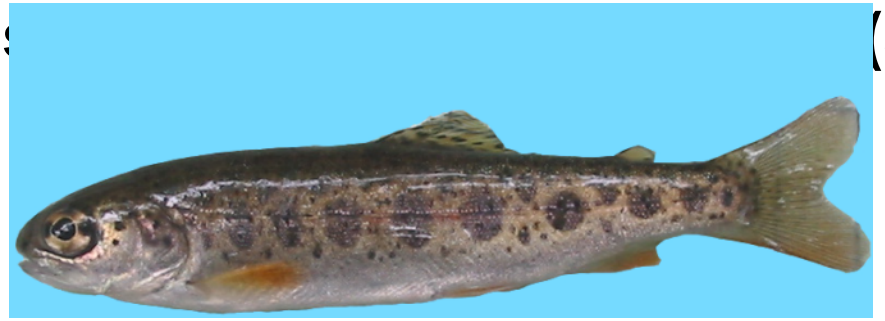
Salmonid Estuary Use



Survival and Growth by Habitat



Steelhead in Scott Creek

Typical s  **(smolt?)**

After 5-6 months rearing in estuary

~10-20% of “smolts” survive, but comprise 85% of returning adults

100mm

Bond CJFAS 2008

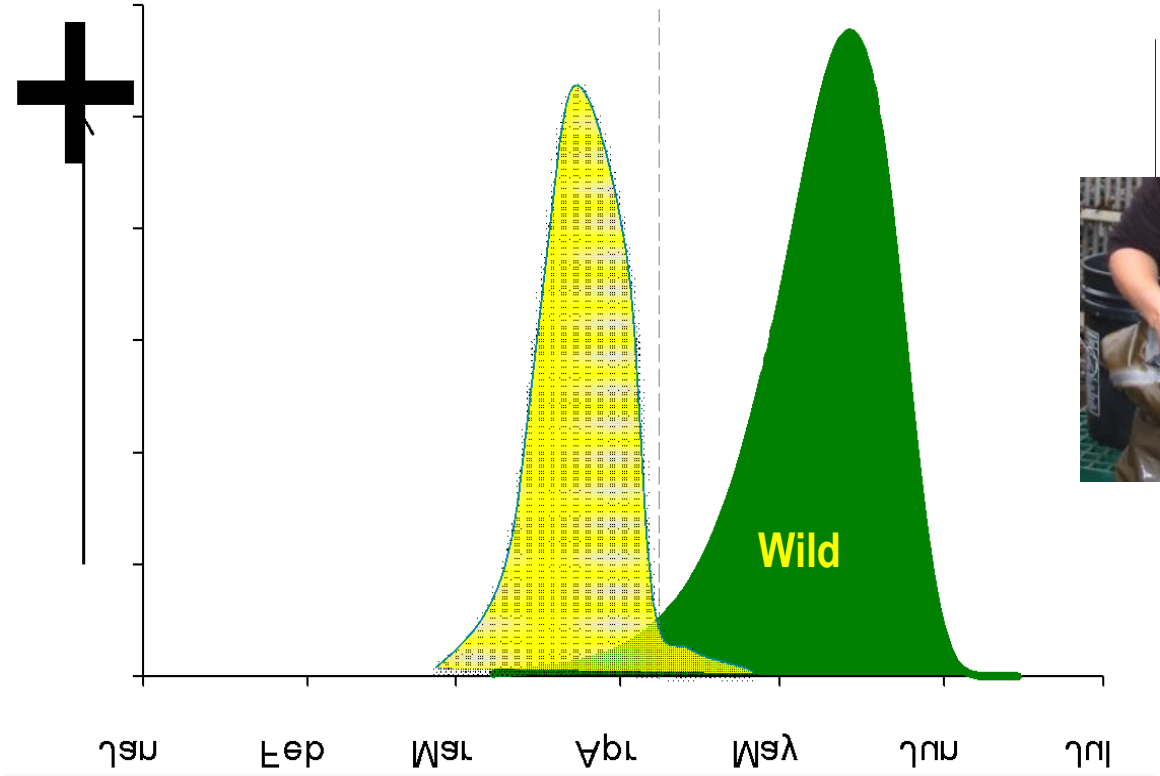

Mine ?
~ 30-50%
of smolts consumed by Western gulls in the last 100 feet of stream!

Status of “southern” coho salmon

- 10 coho recovery watersheds south of S.F. Bay
- Scott Creek only extant population
  - Status/trend monitoring by NOAA since 2002
  - Coho salmon captive broodstock program since 2002
  - Full life cycle monitoring since 2004

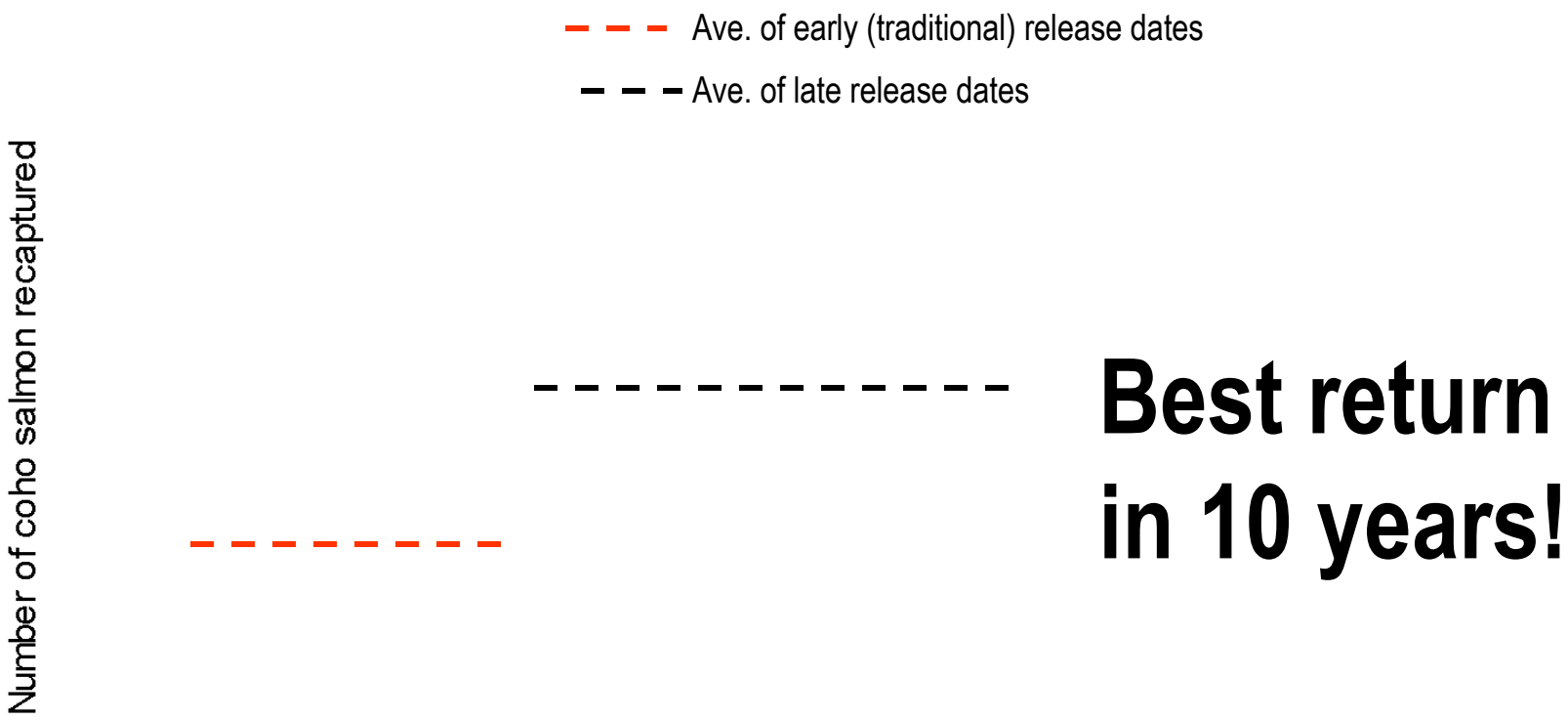
Timing is everything?

Hypothesis: Protracted outmigration timing is an important "bet hedging" strategy against environmental variability



CCC coho salmon

Apparent differences in marine survival among release groups



Prelim. data as of 2/28/15

Lessons From Scott Creek

- Estuaries support dominant life history type
  - High predation balanced by high growth
  - Critical habitat loss across all ESA listed DPS's
- Coho Salmon Broodstock Program
  - Slow learning curve with husbandry
  - Release strategy critical

Salmon River, Oregon

Photo: Carey Smith, Pacific Coast Joint Venture, Vancouver, WA

Purpose

Determine whether recovery of tidal wetlands in Salmon River estuary has benefited Chinook and coho salmon, as indicated by:

- Juvenile habitat use and performance within the estuary (residency, foraging success, growth)
- Population response within the basin (life history diversity, production, resilience)

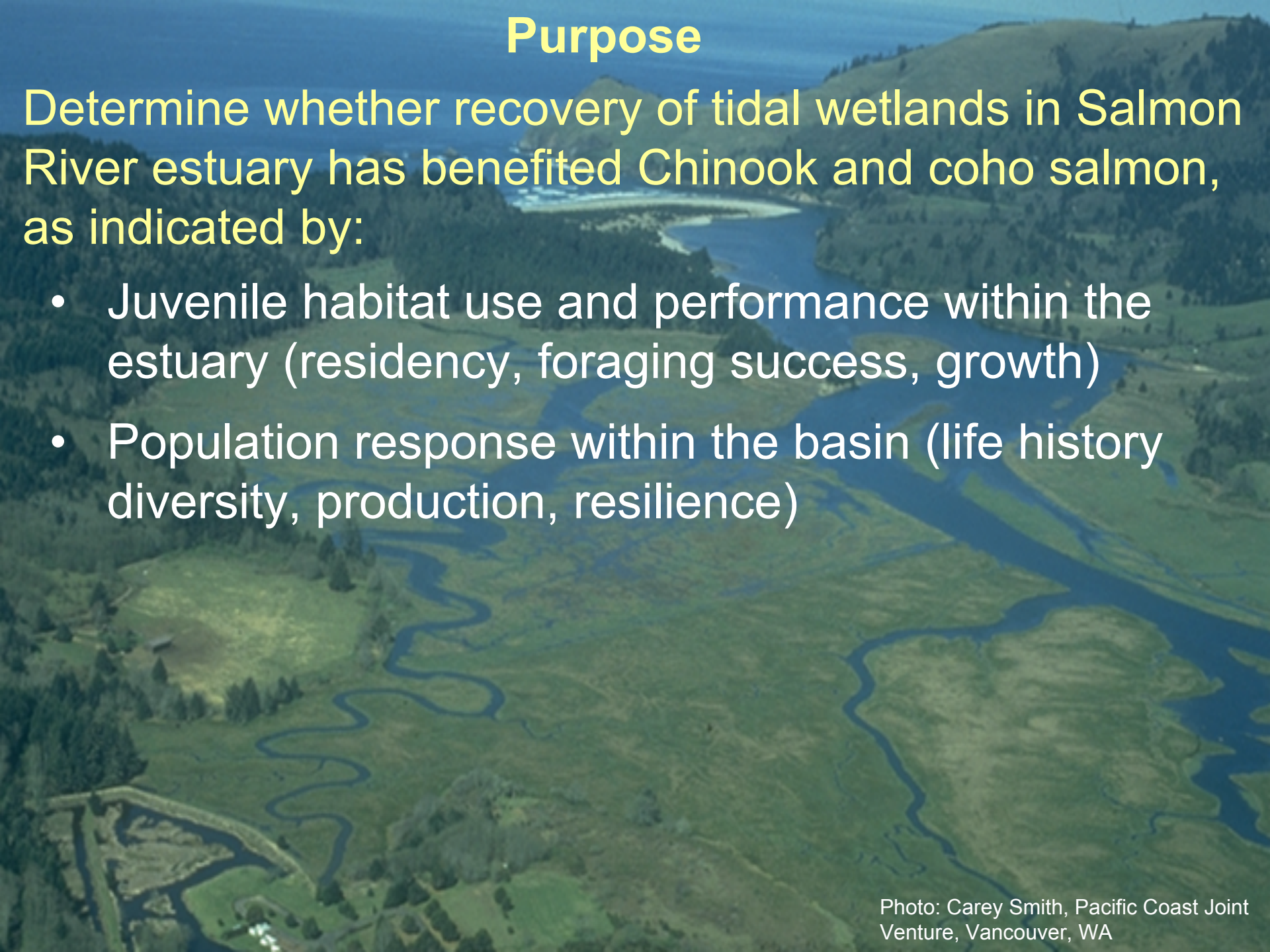
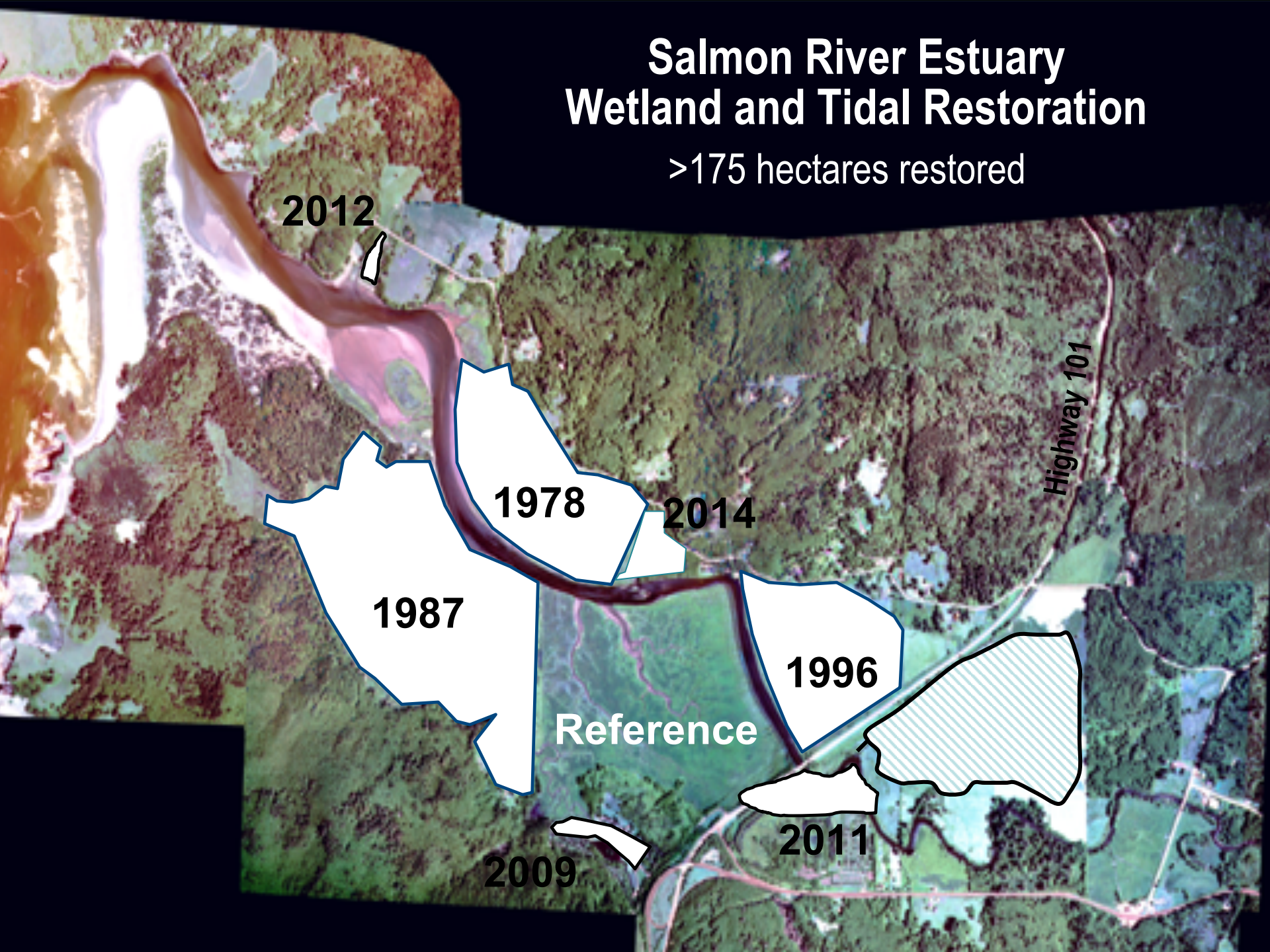
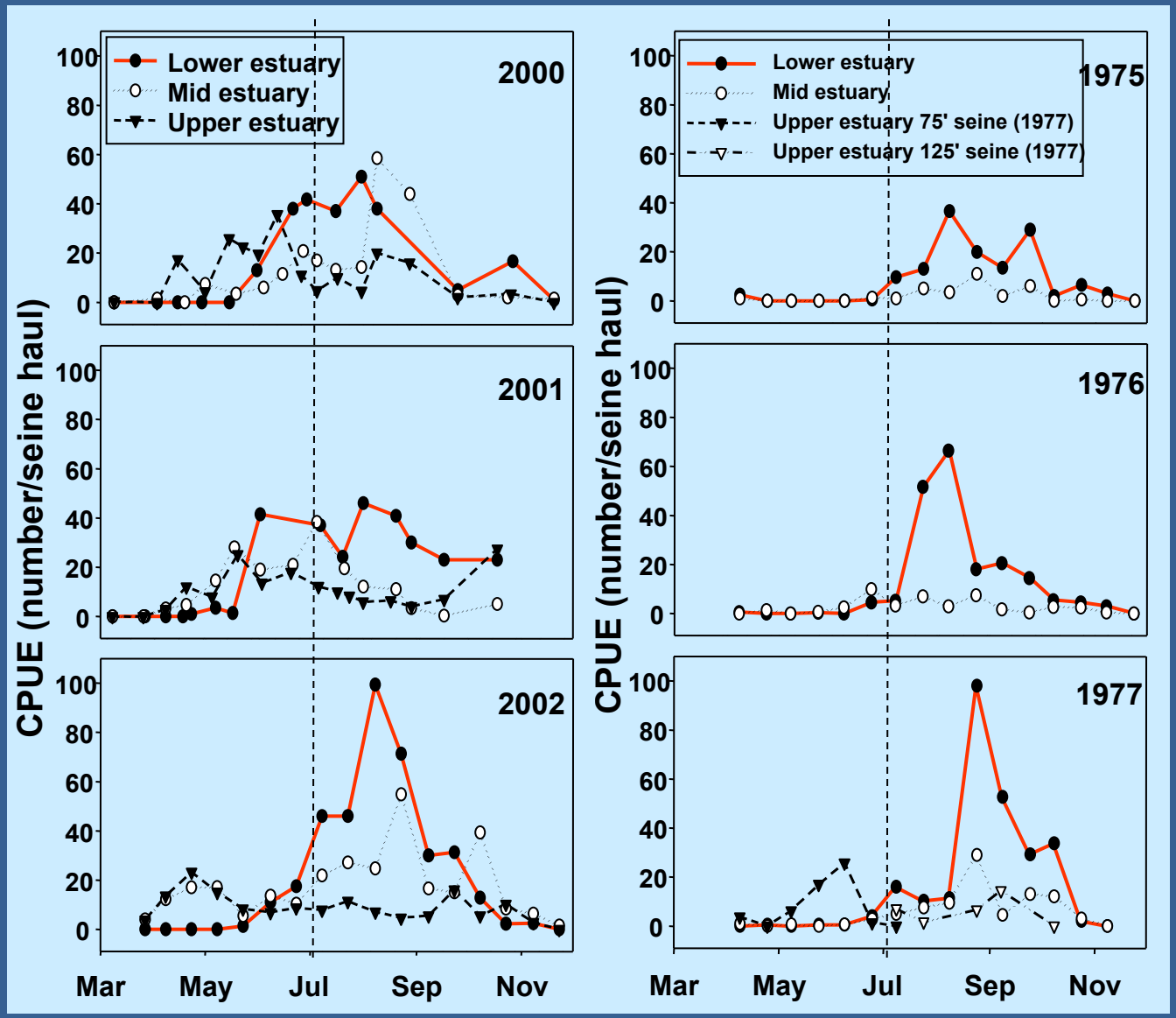


Photo: Carey Smith, Pacific Coast Joint Venture, Vancouver, WA


Salmon River Estuary
Wetland and Tidal Restoration
>175 hectares restored
2012
1978
2014
1987
1996
Reference
2011
2009
Highway 101

Life history diversity has expanded with increased estuarine rearing opportunity



All Life History Types Contribute to Returning Adult Population for Chinook

- 25 – 40% of spawners in 2004-05 were spring migrants
- Spring migrants rare or absent when the marshes were diked

Run Year 2004 (n=145)

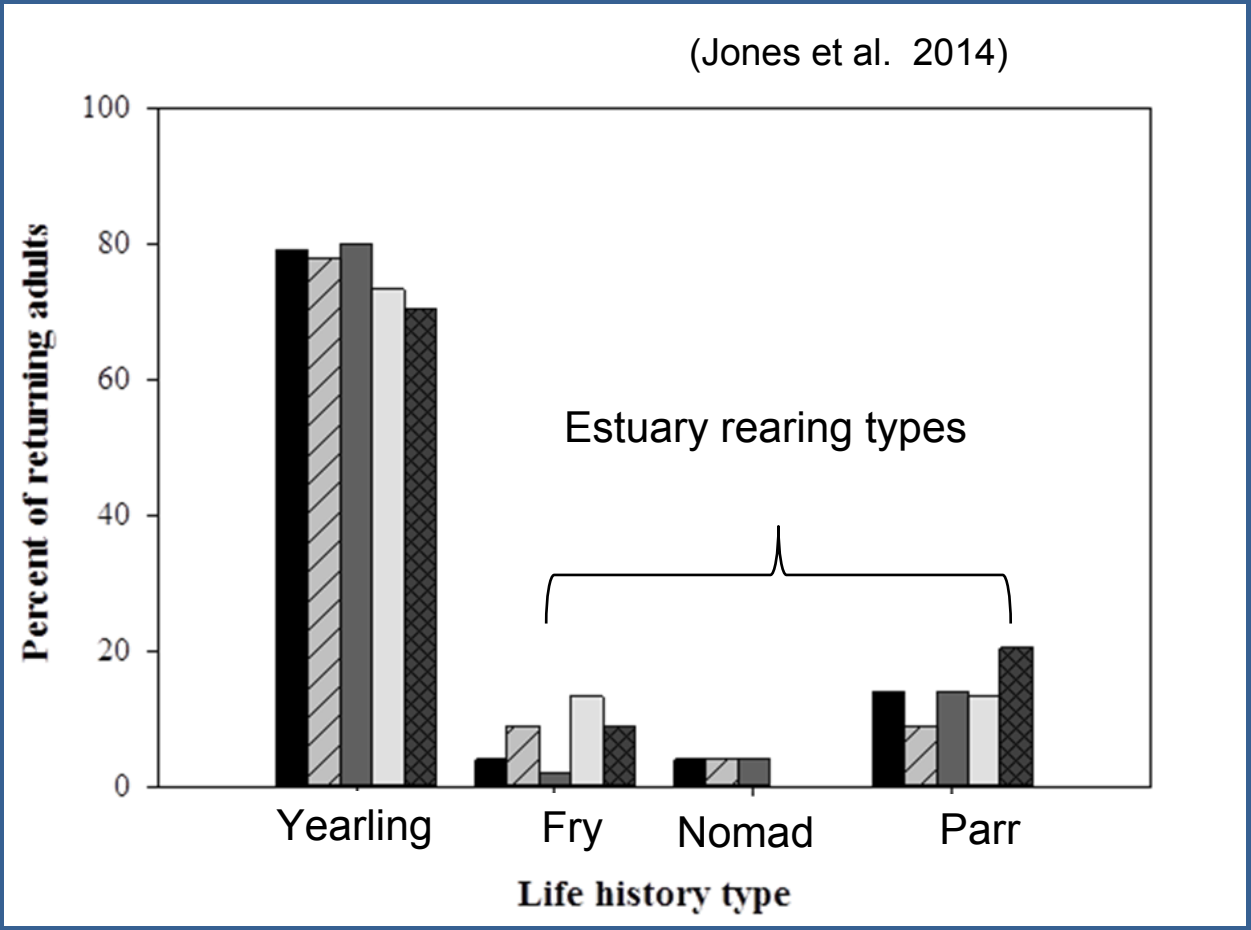
Run Year 2005 (n=85)

Size at Estuary Entry (mm FL)

Emergent Fry	< 45
Spring (MAM)	45-60
Summer (JJA)	60-95
Fall (SON)	>95

(L. Campbell unpubl. data)

Juvenile Life Histories of Returning Adult Coho



- 20-35% of returning adults had reared in the estuary
- Estuary life histories were absent when marshes diked
- Estuary restoration has increased life history diversity AND production

Lessons Learned Salmon River

1. Build it and they will come
2. Estuary habitats promote diversity and resilience
3. Multiple life stages including those that are estuary dependent contribute to returning adults.
4. Estuary restoration is critical to salmon recovery for both coho and Chinook
5. Coho have more diversity than we commonly assumed.

Photo: Carey Smith, Pacific Coast Joint Venture, Vancouver, WA

The Contribution of Tidal Fluvial Habitats in the Columbia River Estuary to the Recovery of Diverse Salmon ESUs

Sponsors:

- U.S. Army Corps of Engineers
- NOAA Fisheries

US Army Corps of Engineers ®
Portland District

NOAA

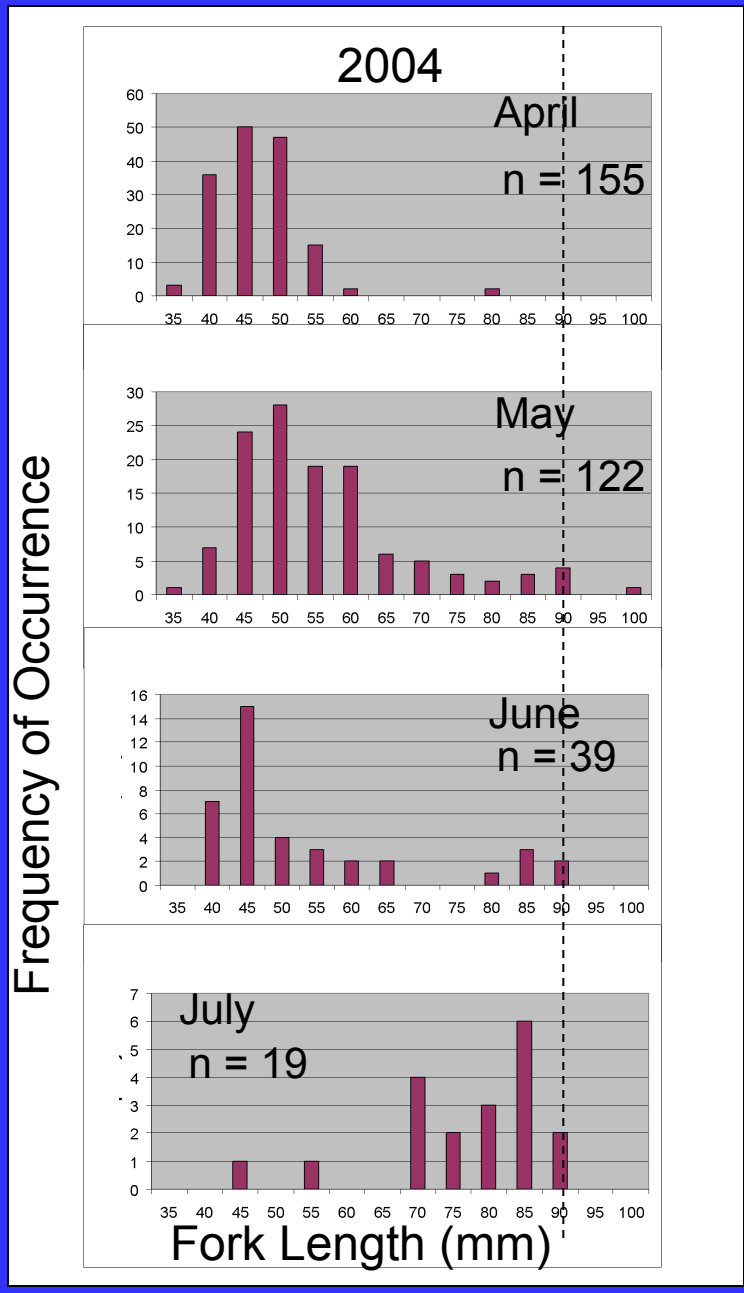
Columbia River

- Despite years of studying fish in the system, most attention had focused on larger life history types.
- Little attention had been paid to the massive wetland system below Bonneville Dam.
- Question 1: Will improvements in quantity and quality of estuarine rearing habitat promote salmon recovery and how do we measure it?
- Question 2: What types and spatial distribution of estuarine habitats must be restored to satisfy the migratory and rearing requirements of diverse CR stocks and life history types?

Habitat use by juvenile Chinook is size-related

- Small size classes frequent shallow, nearshore and wetland habitats
- Few juveniles > 90 mm enter or remain in interior marsh channels

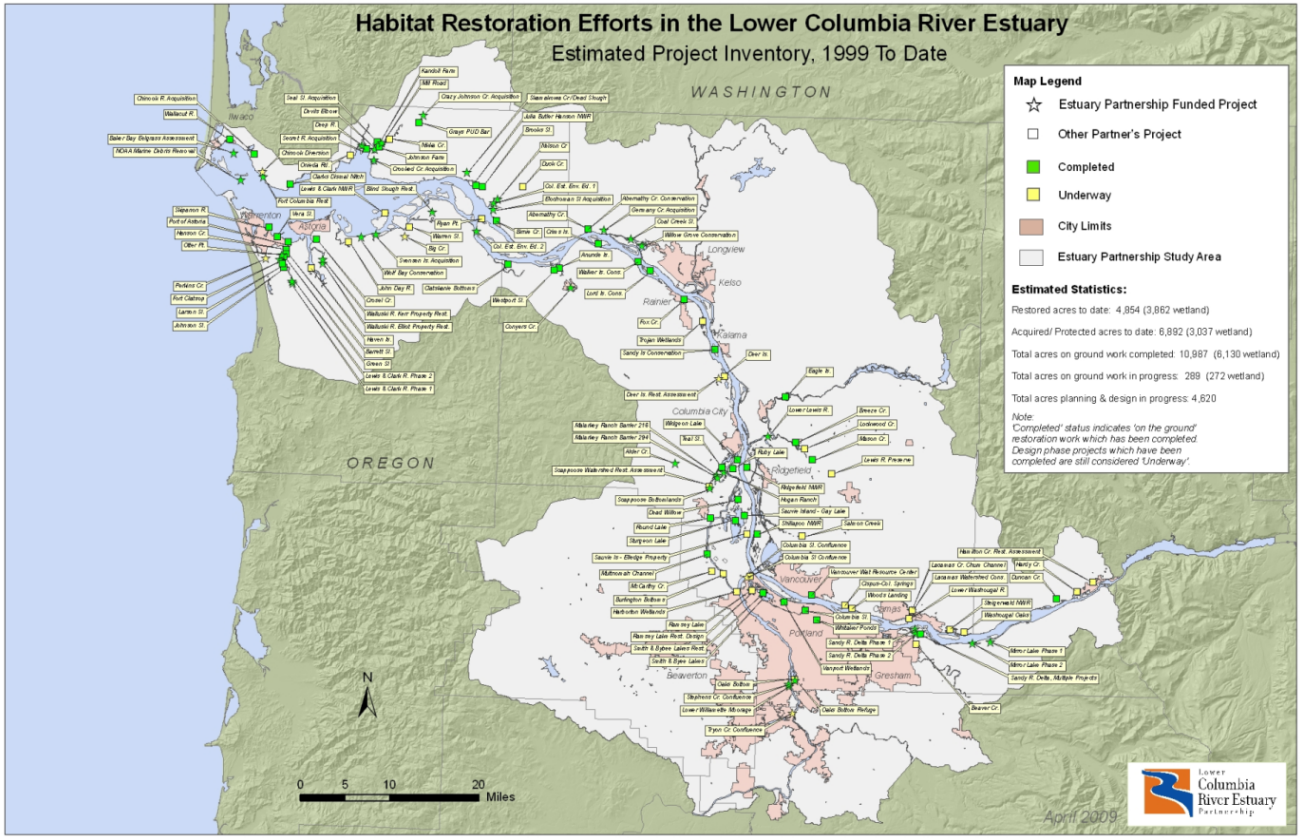
Chinook Length Frequency in Wetland Channels



Lessons Learned, Columbia River

- Many juvenile life histories contribute to adult returns.
- The entire estuarine habitat sequence is used by (and benefits) yearlings and subyearlings.
- Use of the estuary varies with population and fish size that depend upon upstr/downstr and lateral connectivity of the habitats.
- Diverse ESUs and species frequent shallow wetland channels.
- Chinook salmon life histories within an ESU are not fixed. Willamette Spring Chinook produce both yearl. and subyearl.

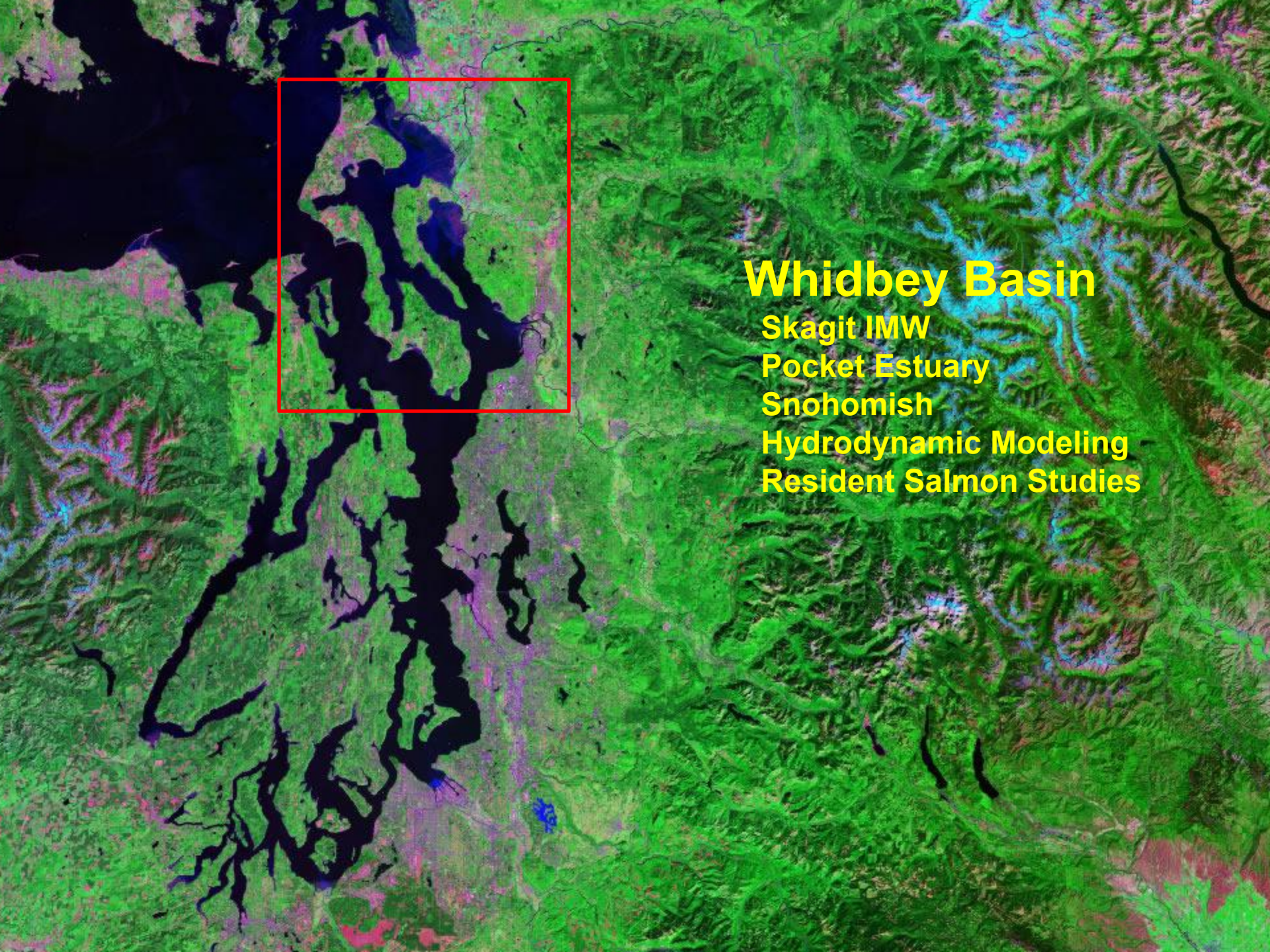
Major Investments in Wetland Restoration in the Columbia River Has Occurred in Part due to Science Center Efforts



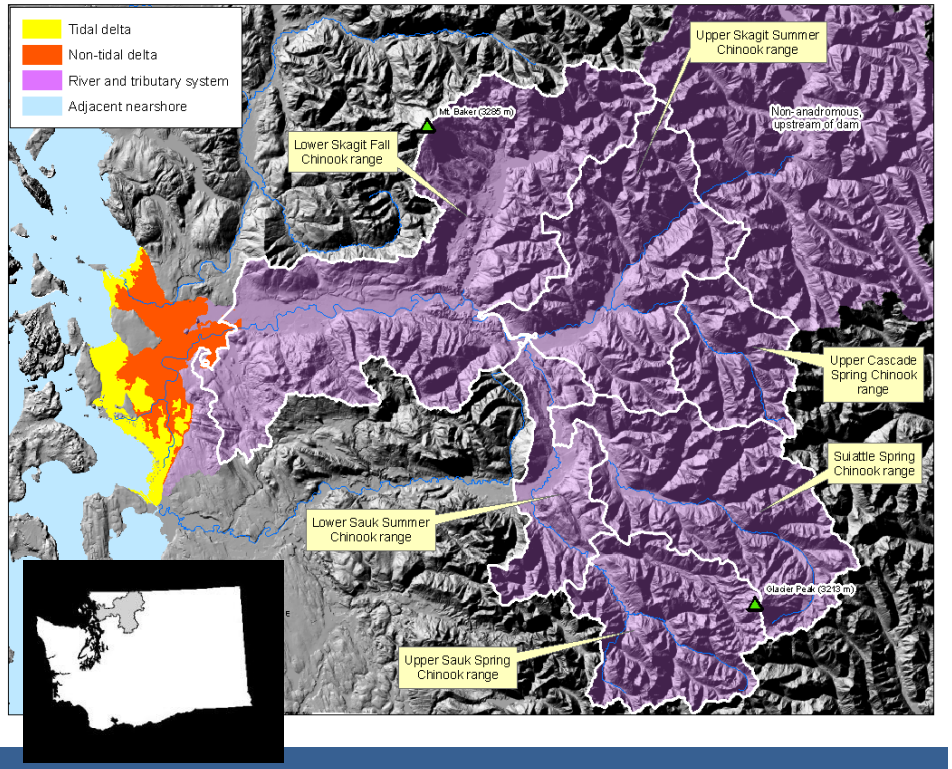
Puget Sound

- Will improvements in quantity and quality of estuarine rearing habitat promote salmon recovery and how do we measure it?

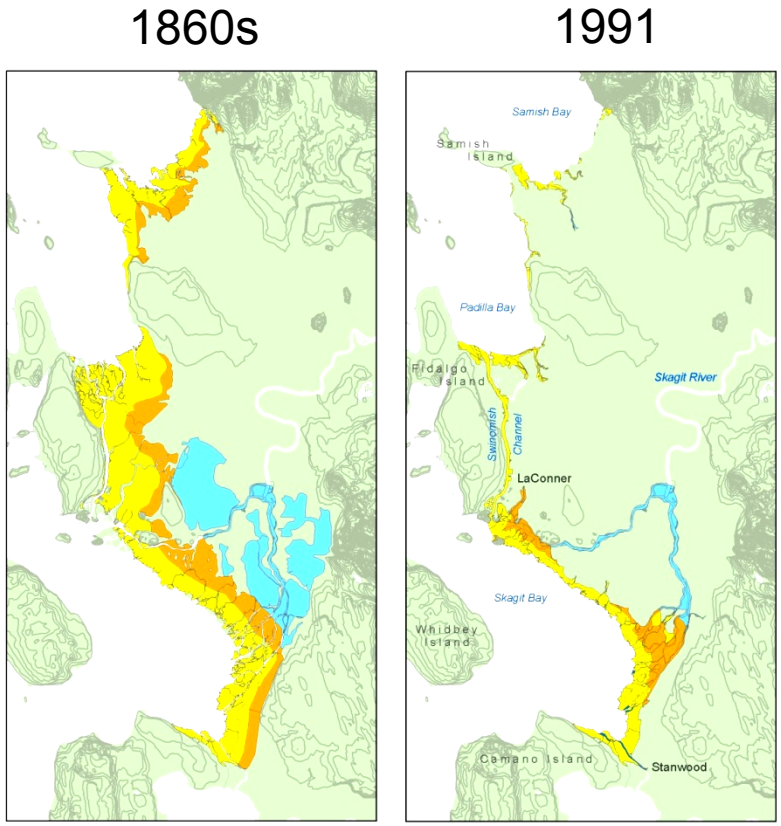
- Complicated Ecosystem.
  - It is a system of estuaries with 2500 miles of connecting shoreline. Different populations produced by different river systems. Different context and setting in each estuary.
  - Land use impacts. Both urban and agriculture are important


Whidbey Basin
Skagit IMW
Pocket Estuary
Snohomish
Hydrodynamic Modeling
Resident Salmon Studies

The Skagit River Intensively Monitored Watershed Project



Largest watershed in Puget Sound
Largest populations of Chinook salmon
Watershed in excellent condition
Relatively small hatchery program



85% loss of estuarine wetland habitats

Objectives

- Determine system-level responses of juvenile Chinook salmon to estuary restoration
- Determine what types of restoration are most effective at restoring connectivity & capacity in the estuary

Collaborators and cooperators

NW Fisheries Science Center

- Lead analyses, nearshore surface trawling

Skagit River System Cooperative (Tribes)

- Estuary and beach seine programs

WA Department of Fish and Wildlife

- Outmigrant trapping in-river

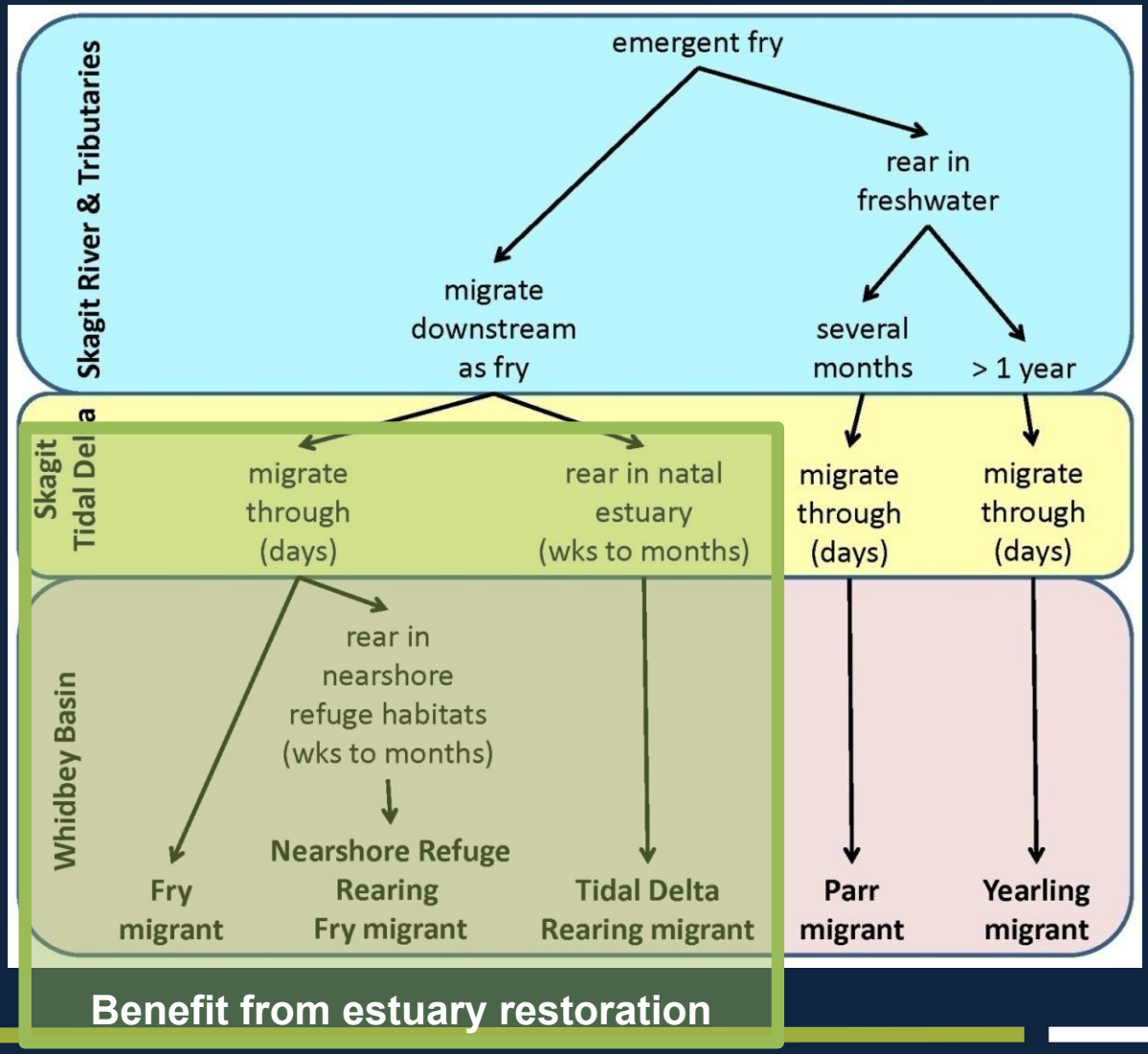
University of Washington

- Collaborations (e.g., zooplankton)

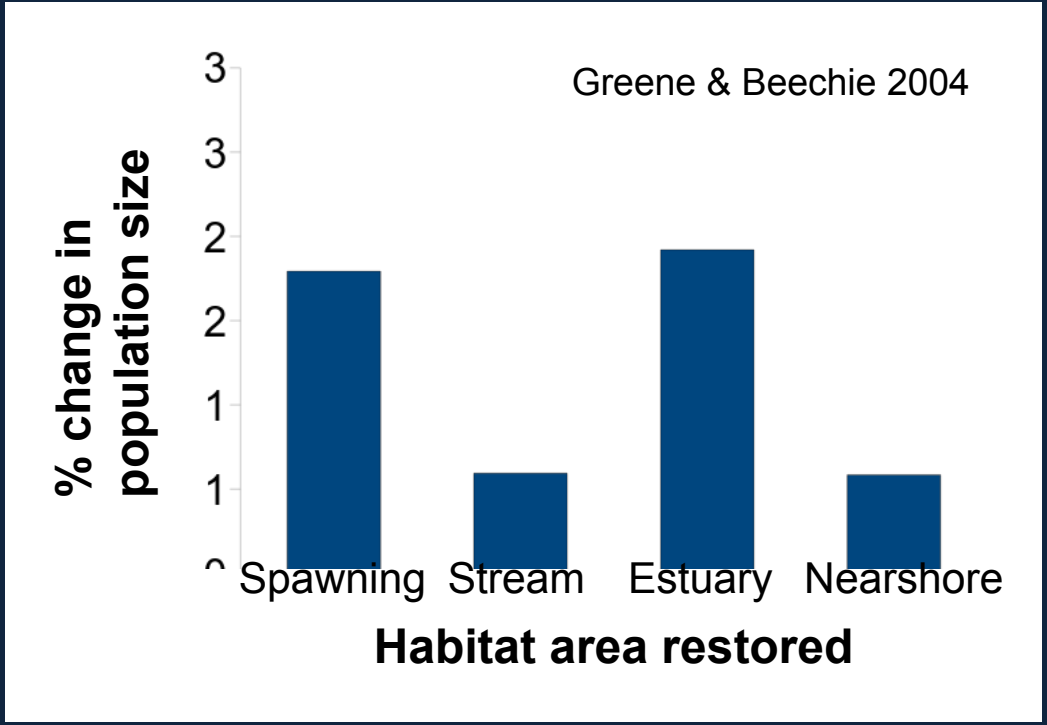
Value of Life Cycle Approach and Time Series

	Habitat	Years	Key fish metrics
Screw trap	Mainstem	21	Outmigrants & fry Size & residence time
Fyke traps	Tidal delta	23	Average & Cum. density Size & residence time
Beach seines	Nearshore	20	Average & Cum. density Freq. of fry migrants Size & residence time
Surface trawls	Neritic	14	Average, Cum. density Size & residence time
Adult counts	Spawning grounds	35	Marine survival, SAR

Different Life Histories Benefit from Estuary



Life cycle modeling: Estuary restoration offers greatest benefits across Chinook life cycle

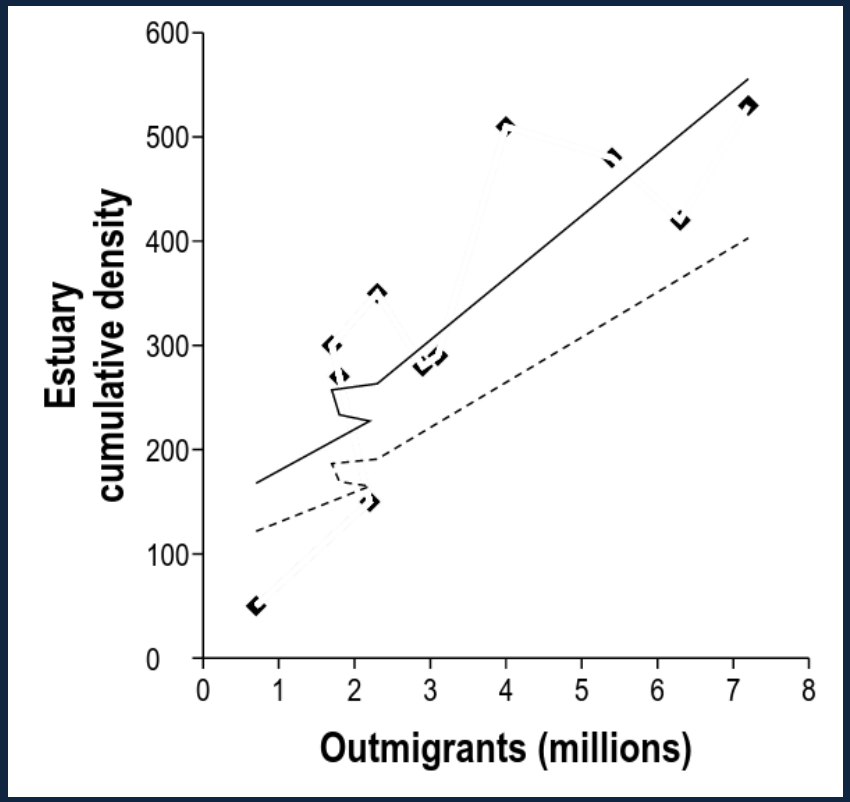


Modeled 10% increase in habitat area

Estuary habitat showed greatest response (higher density, higher survival)

Spawning habitat not limited for most spawning populations (Beechie et al. 2006)

Density Dependent Processes Operating Restoring Estuary Habitat Increases Number of fish rearing there



Post Restoration

Pre Restoration

Lesson Learned- Puget Sound

- **RESTORATION OF ESTUARINE HABITATS WILL SUPPORT SALMON RECOVERY.**
- **IN PUGET SOUND, THIS WORK HAS HELPED TO GENERATE 1000s OF ACRES OF ESTUARY RESTORATION..**

Nisqually Estuary
South Puget Sound

NOAA FISHERIES

Estuary-

Challenges

- Lost several significant studies- Columbia River and Salmon River.
- Estuarine/flood plain life histories- High Risk/High Growth

  Conundrum for BiOps on permitting habitat restoration- how to justify reconnecting fish to high-risk/mortality habitats even when offset by increased marine survival.

Successes

- New studies are being added- $take holder investment
- Future theme: Connectivity between watershed, estuary, ocean, and climate.
- Maintain emphasis on defining population and life history specific differences.
- Many high impact publications to advise management

Opportunities

Critical Estuarine Life histories → Habitat Recovery → Stock Recovery

Ocean

Challenges

- MSA mandates drive ocean science resources to other taxa
- Stake holders don't fund Ocean Science
  - NWC lacks ship time
  - SWC lacks personnel
- MMED impacting NWC time series, and preventing SWC from starting one
- Newport Line time series??

Successes

- SWC and NWC ocean salmon collaboration has been great success.
- Opening the black box: Significant effect of ocean on salmon recovery
- Maintain emphasis on defining population and life history specific differences.

Opportunities

- Potential to merge with other programs to create ecosystem surveys (also a challenge)
- Substantial empirical data sets blending with new modeling tools
  - Improved ecosystem understanding
  - Forecasting tools